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Setting the first knot

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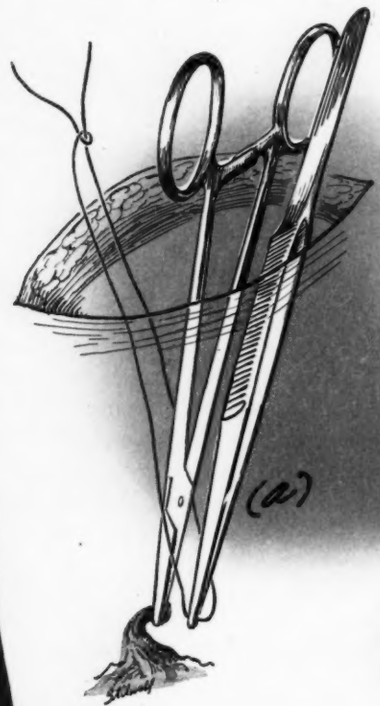


(a)

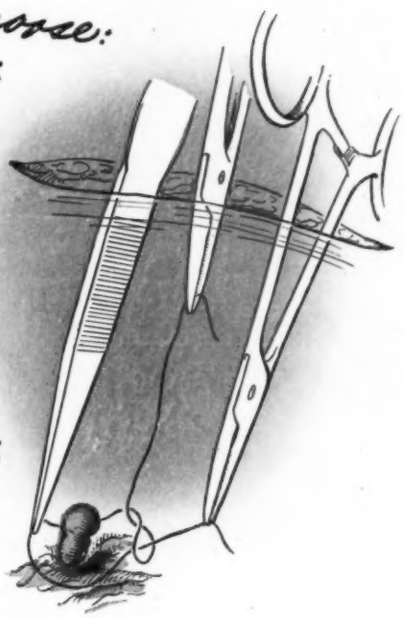
(b)

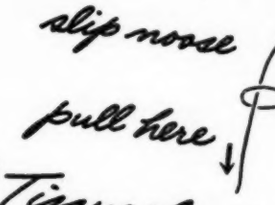
Knot tightened by hand or with clamp, (b)

SUTUREGRAM NUMBER FOUR (CONTINUED)

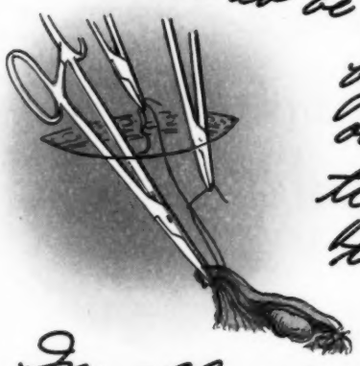
② By special slip noose:
Clamp places loop accurately over structure to be ligated

Example:
small rectal polyp.





③ Tissue to be ligated is transfixed by suture. Knot tied out of hole and tightened down toward this point of fixation.



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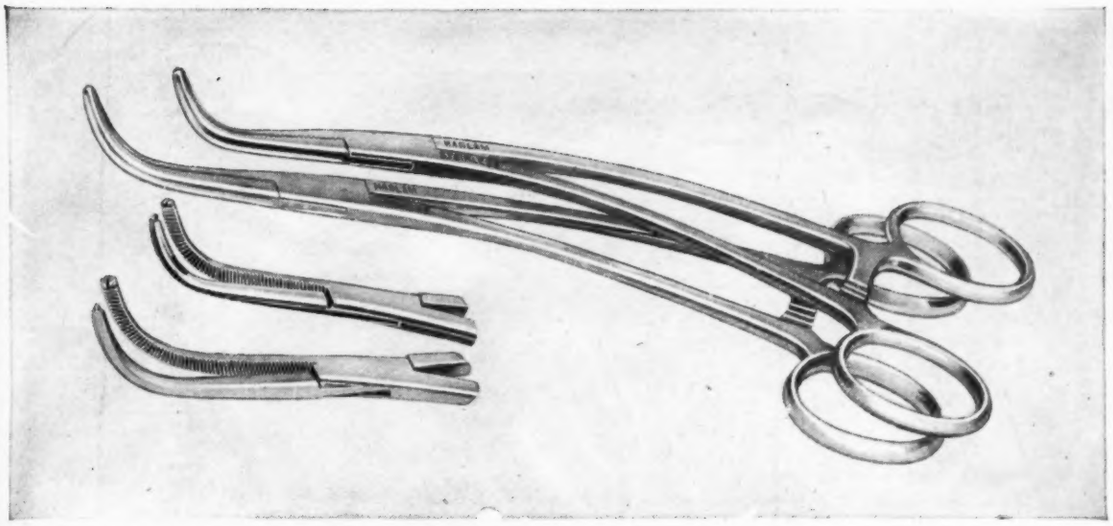

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VOL. LXXIV *Contents • September, 1947* NUMBER Three

Editorial

Instilling the Will to Get Well . . . . . *Loyal A. Shoudy* 231

Original Articles

Survey of Traumatic Surgery . . . . . *John J. Moorhead* 233

Caution in Handling the Extensively Injured. . . . . *Robert H. Kennedy* 241

Contents Continued on Page 3

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VOL. LXXIV — NUMBER Three

Contents • September, 1947

Roentgenology of the Spine in Industry . . . . . *Albert B. Ferguson* 246

Back Injuries in Industry. . . . . *John D. Adams and G. Kenneth Coonse* 258

Operative Indications in Trauma to the Low Back . . *Philip D. Wilson and L. Ramsay Straub* 270

Common Shoulder Injuries. Diagnosis and Treatment . . . . . *Harrison L. McLaughlin* 282

Present Concepts Concerning the Care of the Burned Patient. . . . *William E. Abbott and John Winslow Hirshfeld* 296

Antibiotics in the Surgery of Trauma. . . . . *Conrad R. Lam* 302

Amputation Lessons from the War. . . . . *Henry H. Kessler* 307

Free Tendon Grafts in Secondary Flexor Tendon Repair . . . . . *J. William Littler* 315

Plastic Surgery in Acute Trauma . . . . . *J. Huber Wagner* 322

Plastic Surgery in Industry. . . . . *Claire L. Straith and Matthew A. Pilling* 328

Reconstructive Surgery of the Injured Nail . . . . . *Wilson A. Swanker* 341

Injuries to the Abdomen in Industry . . . . . *Grover C. Penberthy and Clifford D. Benson* 346

Injuries Involving the Genitourinary Tract . . . . . *Walton K. Rexford* 350

Diagnosis and Management of Peripheral Nerve Injury. . . . *E. S. Gurdjian and J. E. Webster* 359

Emergency Eye Care in General Practice . . . . . *F. Bruce Fralick* 368

Chemical Burns of the Human Cornea. . . . . *Ralph S. McLaughlin* 373

Fractures of the Os Calcis. Preliminary Report . . . . . *A. H. Whittaker* 378

New Instruments

Finder and Screw Driver Used in Driving Screws with a Drill . . . . . *Irvin Stein* 380

Self-retaining Skin Hooks. . . . . *Herbert J. Riekert and Raymond K. J. Luomanen* 382

General Information on Page 4 *Advertising Index on 3rd cover*

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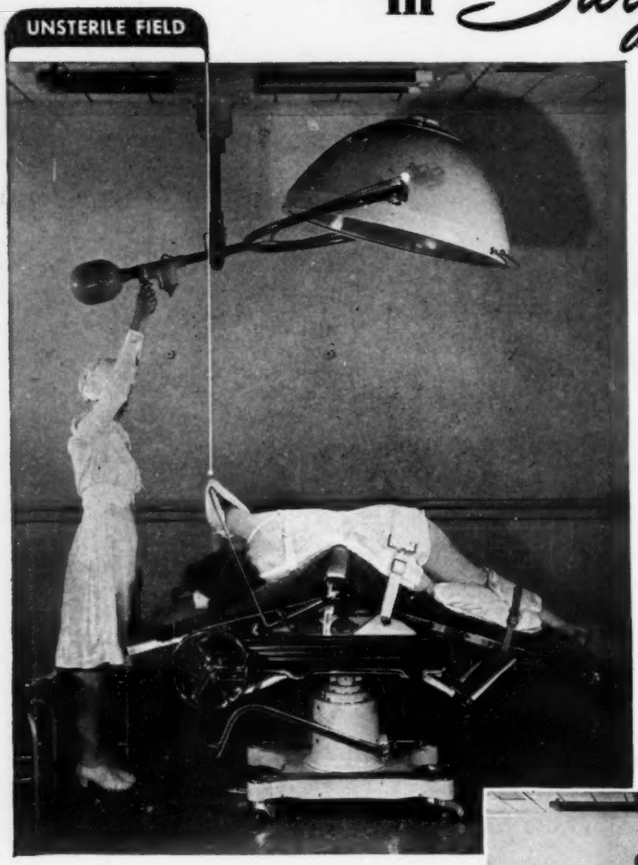

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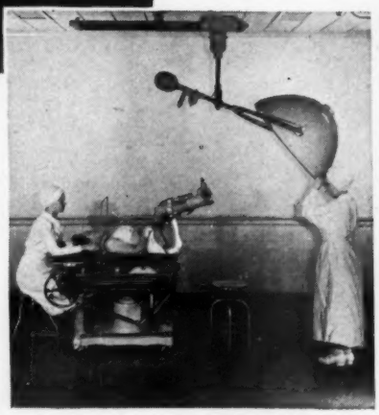

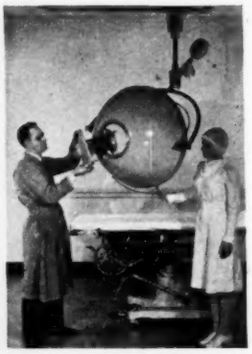

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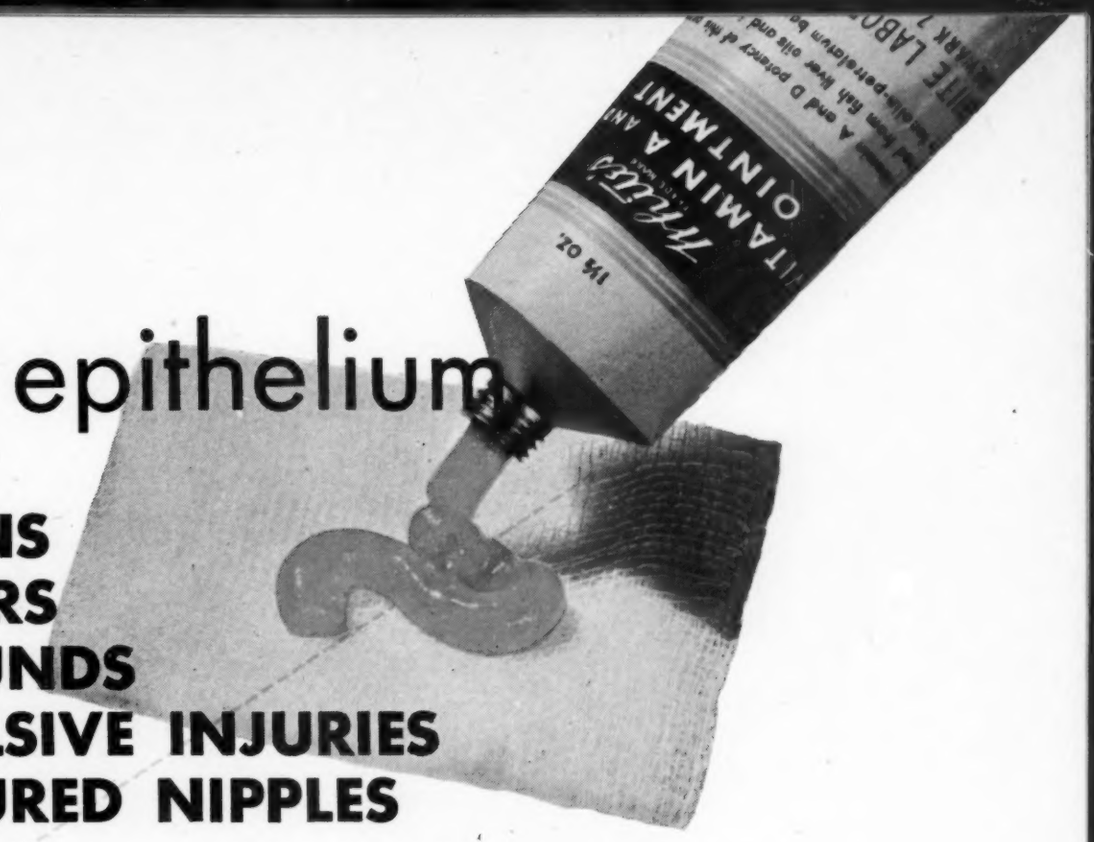

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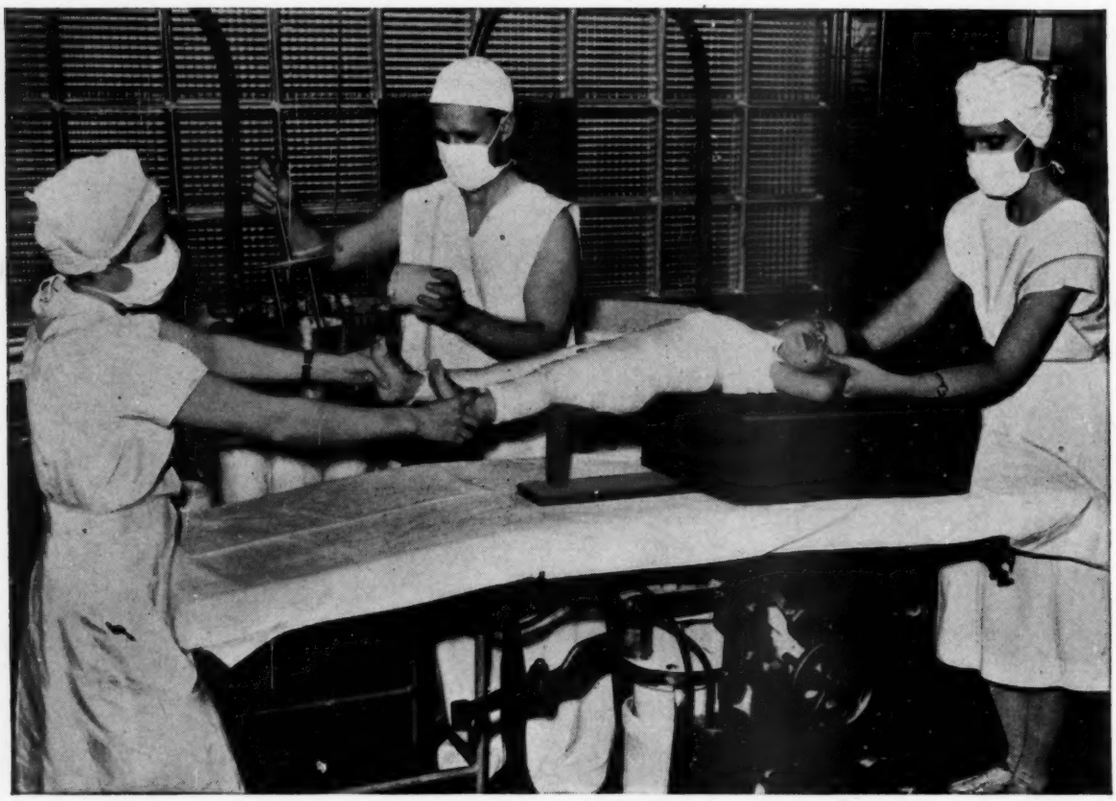

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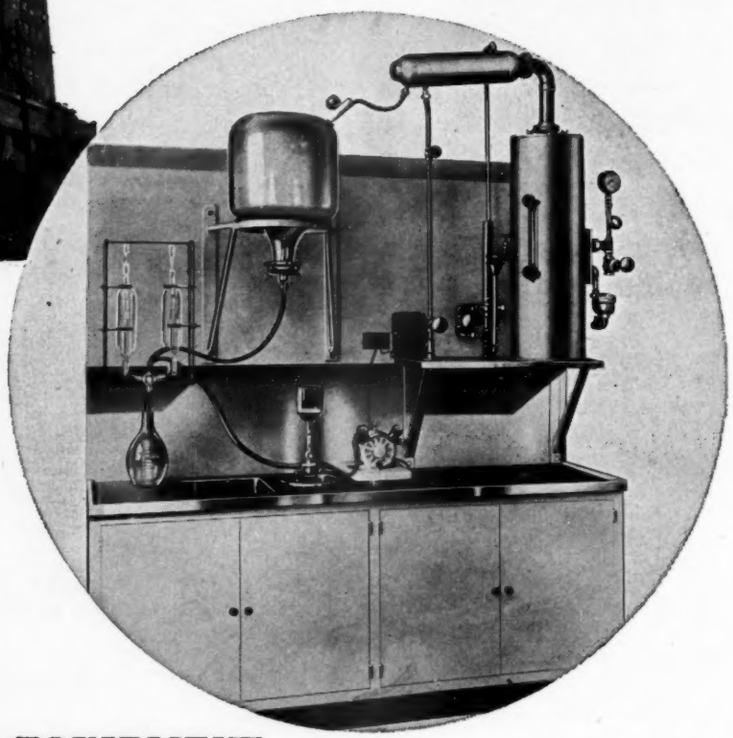

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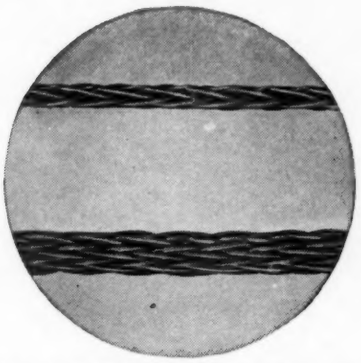

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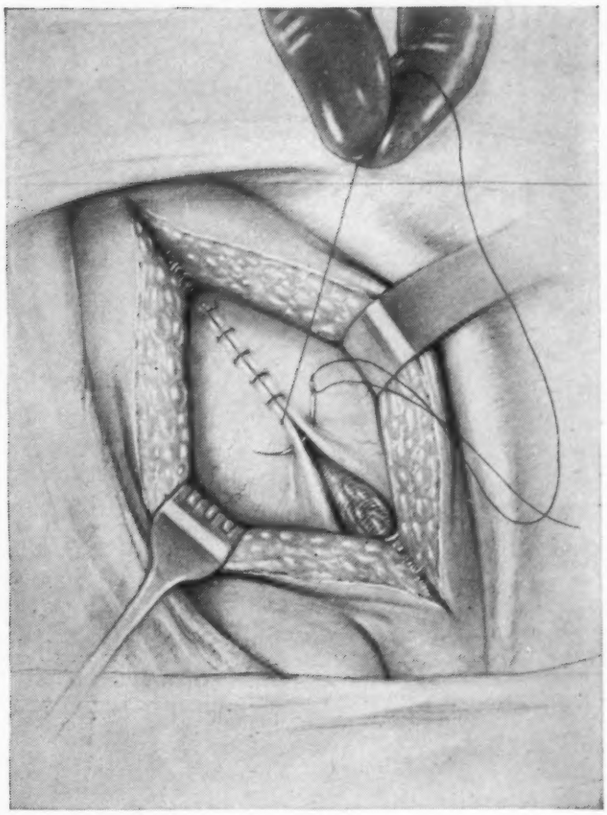

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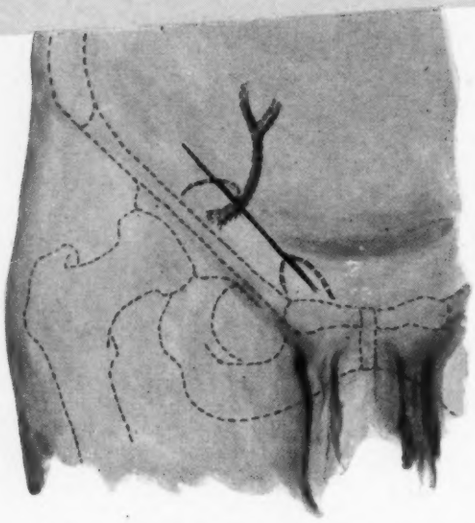
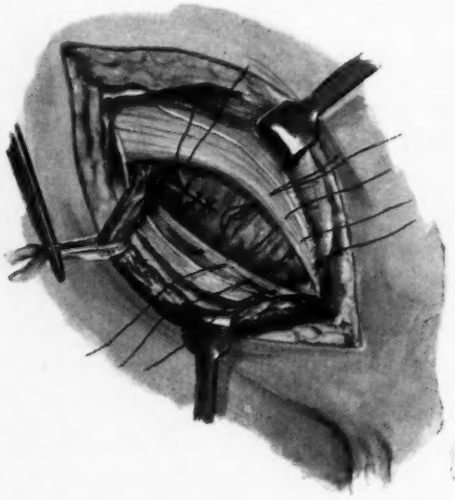


I. Inguinal incision depicted in relation to anatomical landmarks.

II. Aponeurosis of the external oblique muscle incised and retracted to expose the inguinal canal.

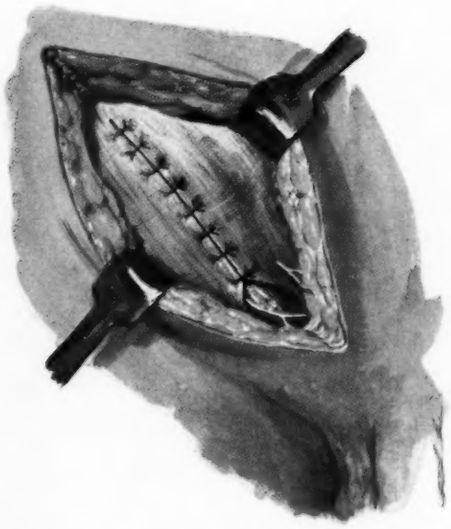


V. Imbrication sutures placed in the transversalis fascia to close the internal inguinal ring snugly about the spermatic cord. Inguinal canal repair begun; conjoined tendon and internal oblique muscle sutured to the shelving margin of Poupart's inguinal ligament.

VI. Bassini type of repair, transplanting the spermatic cord structures external to the internal oblique muscle and conjoined tendon. In children, the spermatic cord is usually not transplanted (Ferguson method).

III. Cremaster muscle fibers incised longitudinally and retracted. The indirect inguinal hernial sac then dissected free from the spermatic cord structures.

IV. Sac mobilized high in the internal inguinal ring and its neck transfixed and doubly ligated before amputation.



VII. Suture of the external oblique aponeurosis over the spermatic cord.

VIII. Halsted method of inguinal repair. The spermatic cord structures emerge superficial to the external oblique aponeurosis and lie subcutaneously.

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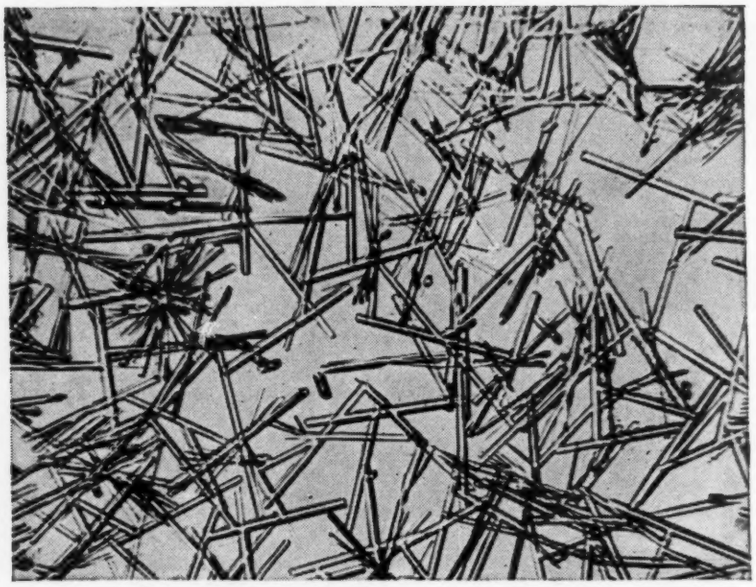

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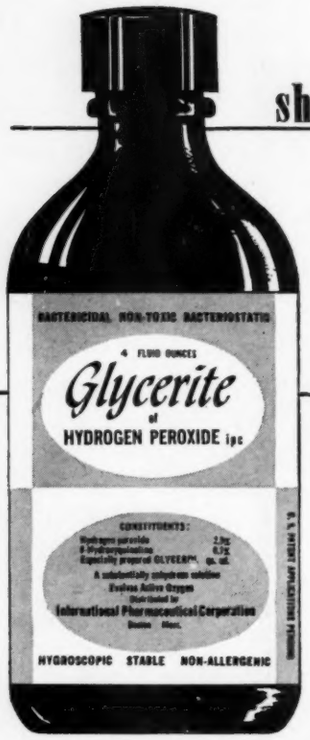

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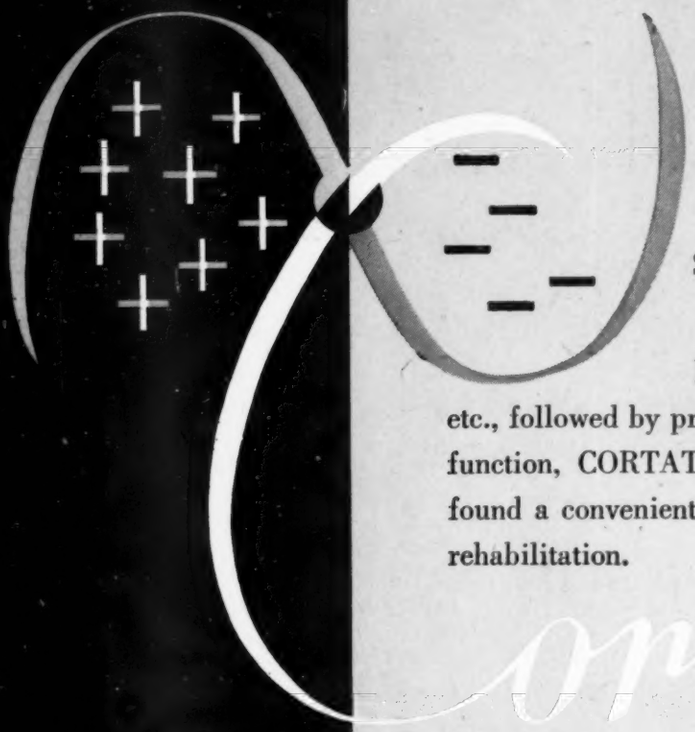

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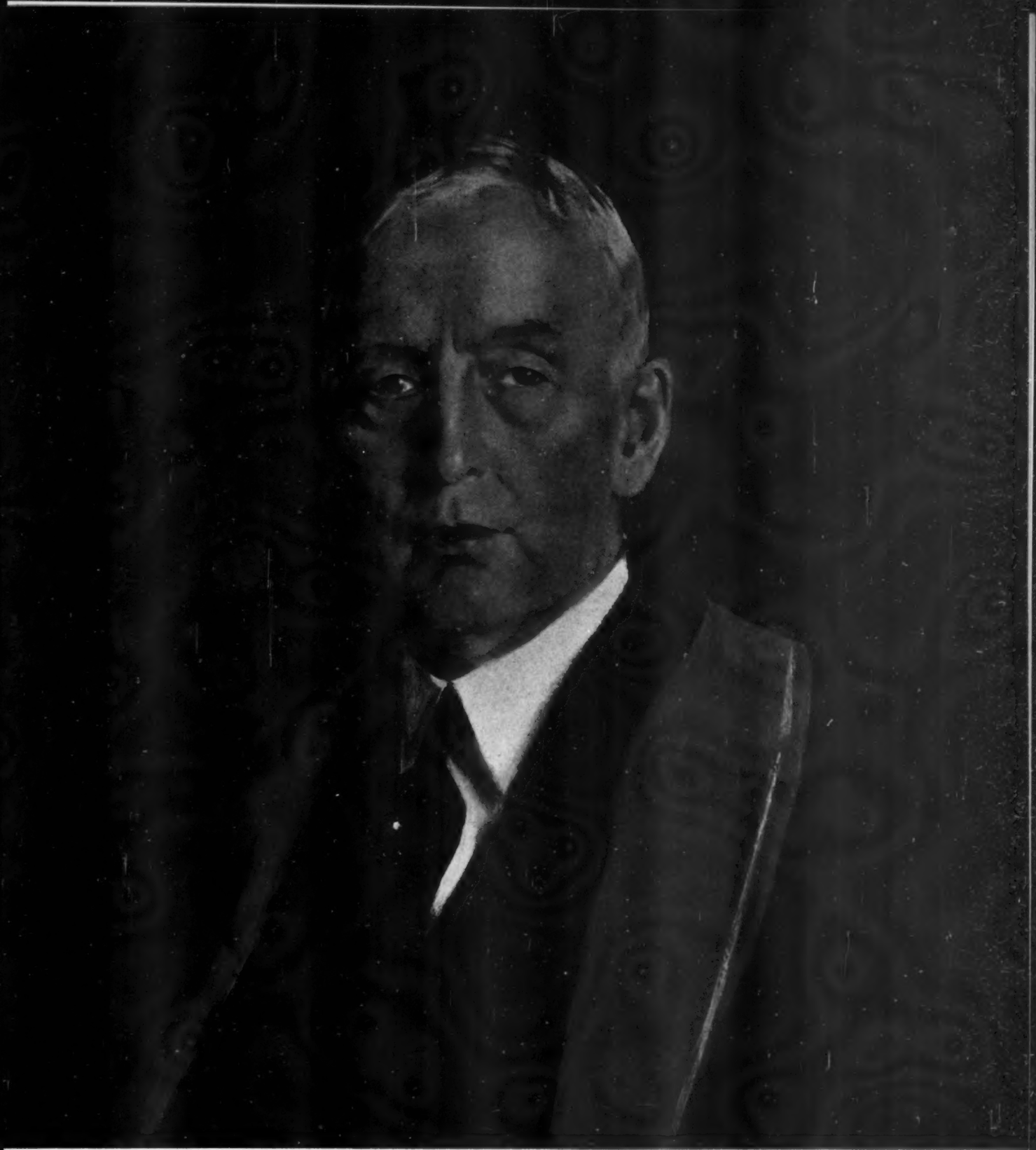

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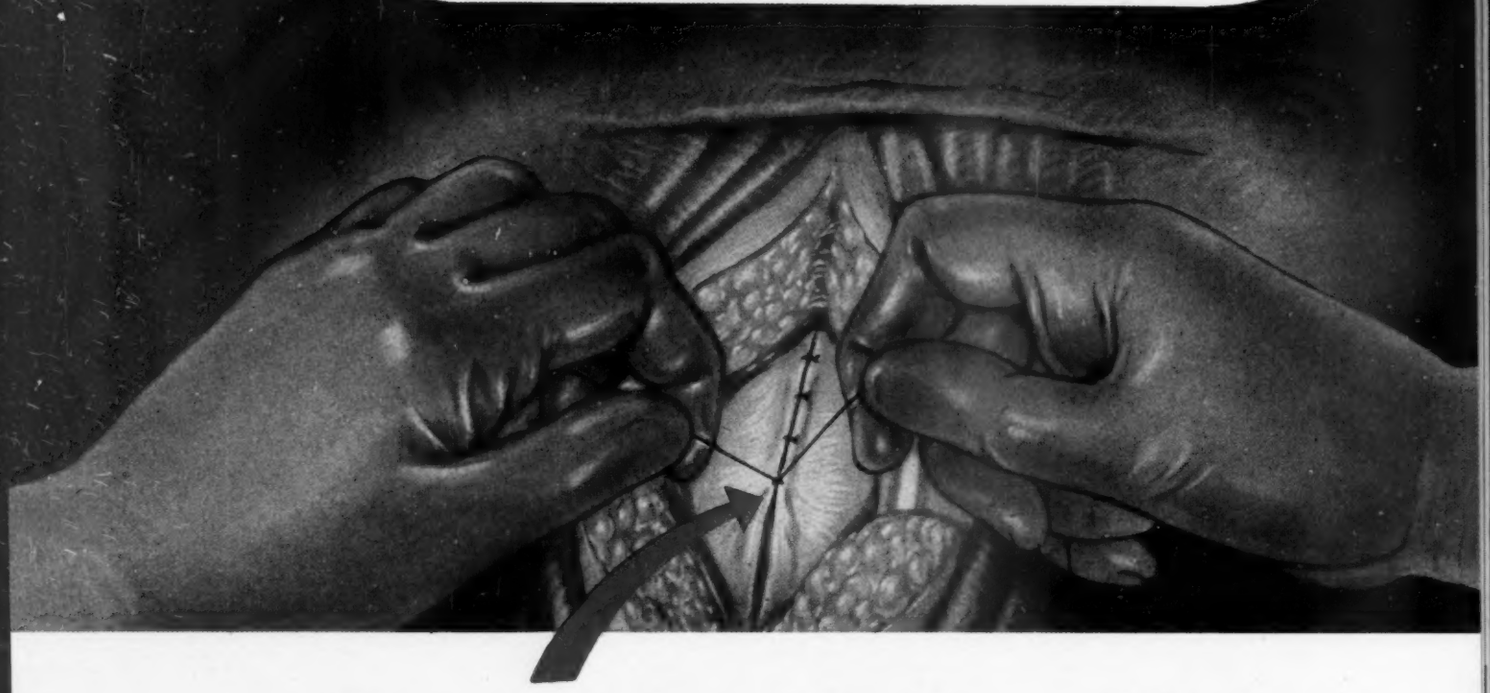

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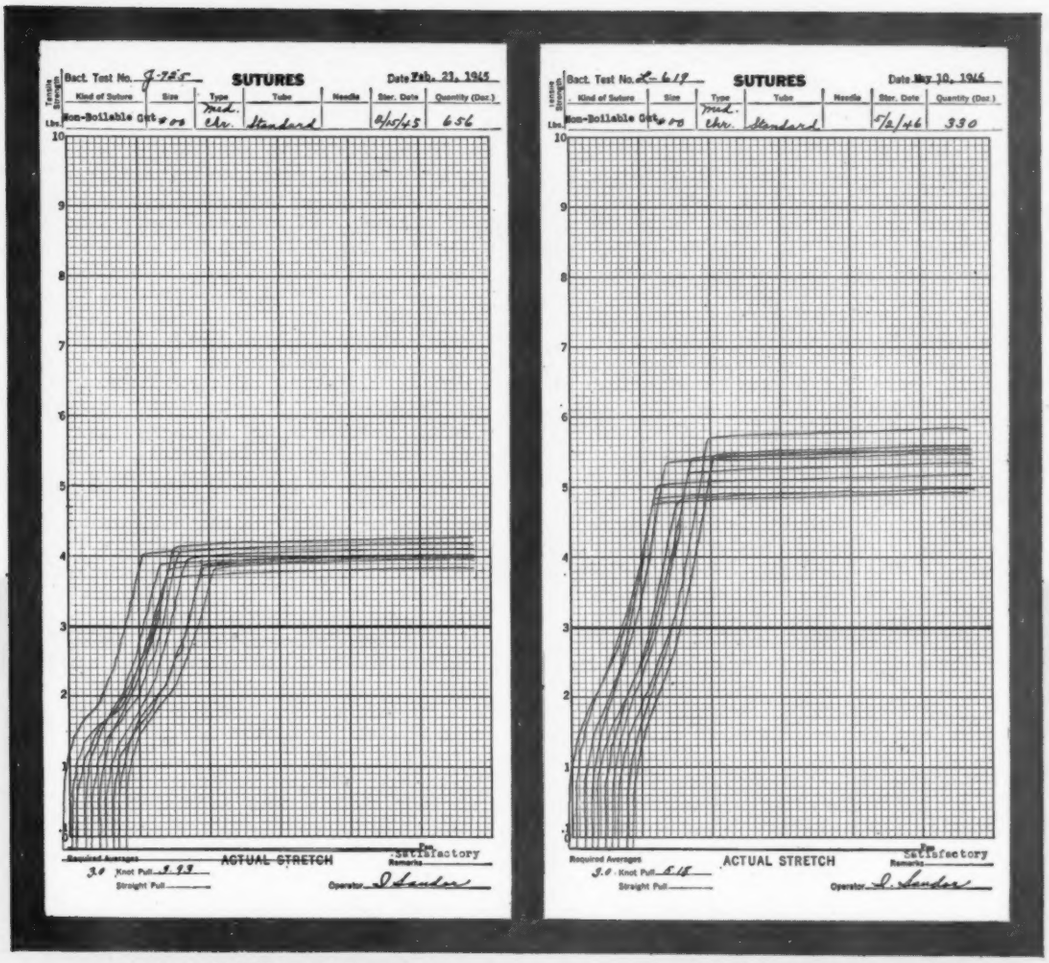

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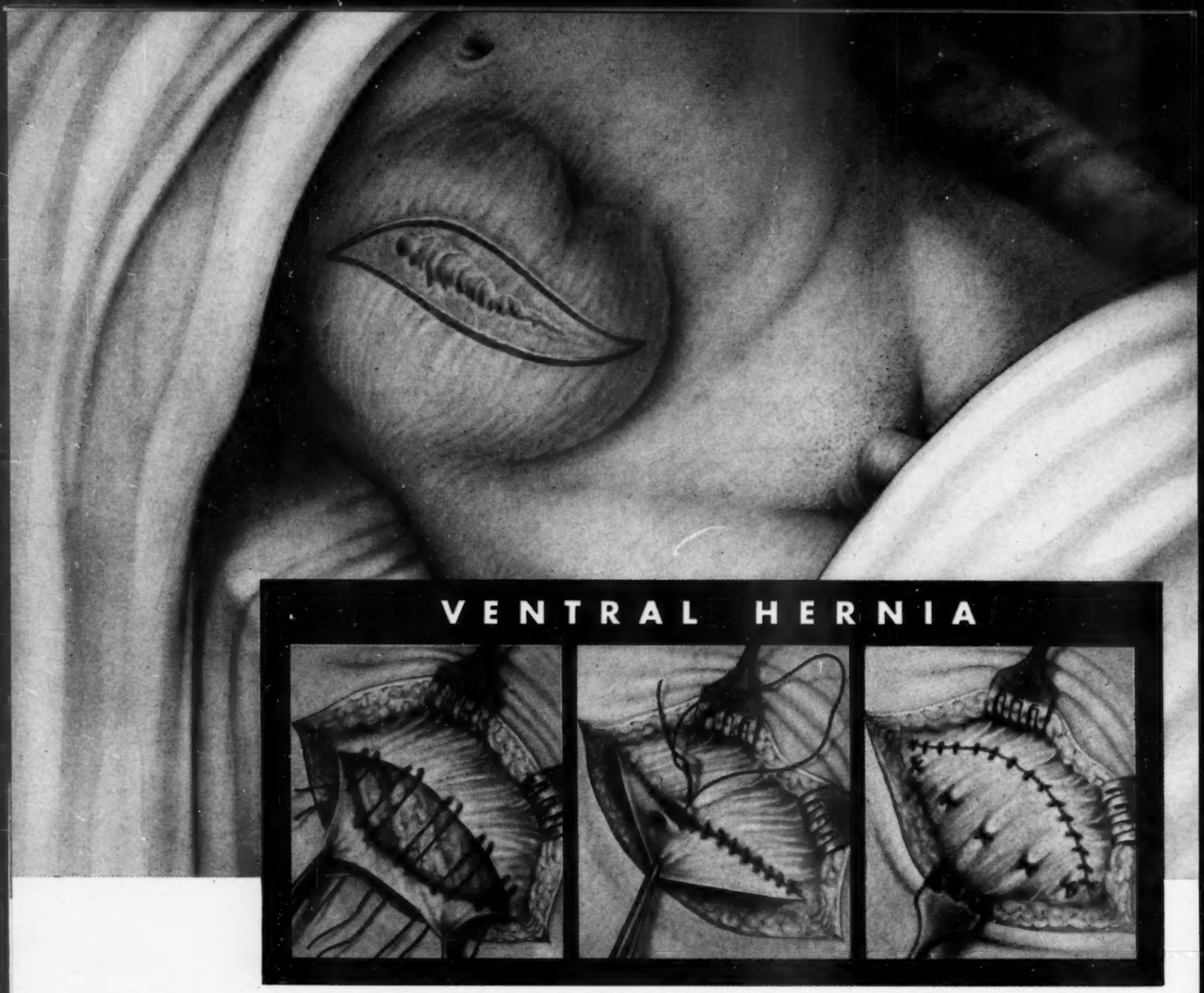

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Editorial

INSTILLING THE WILL TO GET WELL

FOR years we have called attention to the "Humanics of Industry," insisting that consideration should be given to the needs of the injured workman himself as well as to his injury. This theme was ably presented in The American Journal of Surgery, February, 1942, by Robert H. Kennedy who stressed the fact that the injured man is not a sick man and must not be treated as one. We have seen instances in which disproportionate and prolonged disability has resulted from too little attention to the needs of the individual during his convalescence, even when skillful treatment has been given to the injured part. With the development of finer hospital facilities and greatly improved surgical technics we have come to the realization that these are important but not exclusive factors in the successful repair and rehabilitation of the injured. The importance of a proper emotional adjustment on the part of the workman to his injury has become increasingly apparent and enforced periods of prolonged inactivity are now recognized as being detrimental to the human machine as a whole.

Occupational therapy has come to occupy an important place in the treatment and rehabilitation of the injured workman and excellent results are obtainable by the early performance of selected tasks. Not so well recognized, however, is the danger of allowing the patient to settle into a "therapeutic rut." We believe that "work therapy" should replace occupational therapy as soon as it can be done with safety and in most instances industry, recognizing its obligation to the injured workman, is eager to cooperate in the suitable placement of its employees. Our experience in the application of work therapy, however, prompts a word of warning. The morale of the worker is given an immediate lift when he is given the opportunity to "earn as he heals," but to be effective in shortening his period of ultimate recovery his progress from this point must be carefully regulated so that his rehabilitation is continuous and progressive. In most patients it is a mistake to refer to work therapy as "finding an easy job." It is far better to speak of placing the individual on "selected work" for a definite purpose and for a definite period of time. Complete recovery and a return to his original job is often delayed unnecessarily because the worker is permitted to regard an easy job as compensation for his injury rather than as part of a logical therapeutic regimen. The "will to get well" must be instilled. The surgeon must adapt himself to the needs and requirements of industry and the man; the man and his job.

As we review the phenomenal growth of industrial medicine and surgery in the last

two decades, we are impressed with the fact that industry is conscious of its obligation to provide competent treatment for its injured employees and a more critical attitude is taken toward the qualifications of those who would profess to be industrial surgeons. If the surgeon is going to perform industrial (traumatic) surgery, then he should understand industry. Above all he must understand the working man and his problem. Kindness and consideration for the "human machine" must be a part of the treatment. There is, however, an understandable reluctance on the part of many good surgeons to accept industrial accident cases in some parts of the country, which can be traced to an unwillingness to become embroiled in compensation proceedings. The result is that too much of this important work is being done by men whose only qualification is a willingness to assume the risk of spending hours each week in medico-legal joustings with compensation lawyers. Even in those states where industrial physicians are rated or classified on the basis of their qualifications, there is a need for setting higher standards to safeguard the injured workman from incompetent surgical treatment.

The increasing number of able surgeons who are doing excellent work in the treatment of industrial injuries is in a large measure due to the work of such great teachers as Moorehead, Murray, Marble, Magnuson, Gurd and many others who continually spread the gospel of better care of the injured. Much credit reflects on the members of the Committee on Fractures and other Traumas of the American College of Surgeons, for their valuable contribution to the education of the general practitioner in the proper management of injuries and Kanavel, a grand person and able surgeon who left a fitting monument to his memory in his classical "Infections of the Hand."

The proper treatment of small trauma has claimed the attention of such outstanding teachers as Koch and Mason, and justly so, for the care of smashed fingers and similar injuries is an important phase of industrial surgery to which too little consideration has been given in the past. Between major and minor traumatic surgery is that field for which we have often used the term "major-minor surgery." Not so much emphasis has been placed on this phase of surgery but approximately a year ago Bancroft gave us an excellent discussion which is notable for the sound principles expressed.

In this issue of the Journal we have attempted to gather together articles of timely interest to industrial surgeons written by authors who understand their problems and have something new to offer —new ideas, new methods or new points of view. Each is a worth while contribution and we are grateful to the authors for their assistance in the preparation of this issue.

Loyal A. Shoudy, M.D.

Original Articles

SURVEY OF TRAUMATIC SURGERY

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IN any retrospective review of many decades the tendency is to emphasize certain features with which a writer has been personally identified. However, in order not to make the story too replete with the experiences of one individual, it will be the writer's endeavor to survey some of the outstanding gains in the field of traumatic surgery.

Probably the most satisfying element is the very definite place this branch of general surgery has attained. As with other subdivisions of surgery the subject of trauma is now accorded a realm that virtually means at least an approach to specialism. In many teaching institutions and in most hospitals the treatment of traumatic lesions is a segregated feature with the result that students, the profession and the laity are now accident and injury conscious to an extent that was unknown hitherto. The automobile age, the two world wars and the development of industrial practice are among the major factors in this established recognition.

However, the general advance in every surgical endeavor is also a feature, and the stimulus and example set by surgeons in other fields has stimulated those engaged in traumatology to greater endeavor to defeat the three horsemen of trauma—shock, hemorrhage and infection. It is recognized that traumatic surgery differs from general surgery in many essentials, notably in that there is no incubation period in trauma because the effects of external violence register instantly and the patient has no time to build up bodily defenses nor are there any preliminary symptoms. Furthermore, traumatic surgery is essentially a salvaging project and the surgeon who treats the injured is, in reality, a repairman. The general surgeon removes and the traumatic surgeon retains the damaged parts. In trauma a minor injury often is converted into a major catastrophe because of the onset of infection or the presence of some constitutional ailment, such as cardiovascular, pulmonary or diabetic associates. In general surgery these medical factors can be evaluated properly because the time element differs and the emergency features are less immediate. Traumatic surgery is the most nearly public property of any type of surgery and usually is subject to critical review by the patient, family, friends, neighbors and various legal agencies. In fractures the *x*-ray films supply additional evidences, to say nothing of the facial or other scars and the notable limp as the outcome of an automibile mishap. General surgery escapes most of this scrutiny and the postoperative hernia following the laparotomy is rarely discussed except by the patient and the family, and less rarely is the gaping scar exposed to public view. Furthermore, in general surgery the removal of an appendix or a gallbladder is a hazard known to the patient, and the outcome, if unsuccessful, is not charged to the surgeon, as is the case of a fracture of the lower third of the tibia and fibula resulting in non-union or a deforming limp. In a broken bone a cabinetmaker repair is expected by the victim; in a ruptured appendix the patient accepts the outcome and places no blame upon the surgeon who performed the operation, nor does he sue for malpractice if dissatisfied.

In appraising the experiences in traumatology it may simplify the matter if we assume that 80 per cent of traumatic effects register as: (1) wounds; (2) burns; (3) joint and tendon involvement and (4) fractures and dislocations. In all of these we predicate the three major sequelae in trauma which are to be defeated, namely, disability, deformity and death.

Shock, hemorrhage and infection are the three associates, as already indicated, and it is a happy retrospective reflection that all of these are nearly subjugated. We recognize that inevitably certain injuries are fatal because of their site and severity. In another group of major importance, prompt and efficient treatment brings success. A third group is almost invariably recoverable in terms of function and form. Stated in another way, experience teaches that the outcome may be summated by saying that in one group the result is a fatality no matter what we do. In another group recovery is assured whatever we do and in the third group the end result depends on what we do.

Shock in the olden days was recognized by the same cardinal visible signs still prevailing but the differentiation from hemorrhage was baffling and often determined only by operation or autopsy. Likewise, the treatment was varied and very often empirical, lacking animal and laboratory verification. It is true that no universally accepted definition of shock is available but that does not detract from the truism that this destructive agency is now more easily recognized and controlled. The advent of blood, plasma and their derivatives has changed this drab picture so that many useful lives are saved. The day is not far away when a blood substitute will be available and thus this scourge will be more definitely conquered.

Hemorrhage is another foe that decades ago presented visible evidences to the experienced observer, but here also the clinical picture was fogged by shock as the sole or associated factor. Thanks to zealous and careful research this puzzle is also in the process of being solved from a diagnostic standpoint, as cumulative experience has demonstrated the sovereign power of transfusions. Thus, these two elements that defeated any salvage project are no longer in the doubtful stage but actually are en route to defeat.

Infection was the enemy that lurked in every case whenever the surface was broken or there was a known or unknown internal focus of transmission. The use of antiseptics would be a chapter in itself, dating from the carbolic and bichloride days to the present vintage. In World War I it has been asserted that over 200 antiseptics were employed and found wanting. The Dakin's chlorinated solution of that era as administered by the Carrel technic was presumably the sterilisia magna sought by the ancients, and yet at Depage's Hospital at La Panne, Belgium, in December, 1917, the author soon agreed with the Belgian surgeons that this remedy was only an adjunct to the supposedly new technic of débridement. As a matter of fact, Dakin's solution was discarded in many military hospitals abroad before it became popularized in our own country. It is both interesting and instructive to reflect that the Dakin's solution of World War I was chemically a replica of Labarraque's chlorine preparation used a century previously. Débridement, that excision process by which dead or dying tissue is removed, was one of the major permanent lessons of this first war but in reality it had been used in the Napoleonic Wars a hundred years before. Baron Larrey, chief surgeon of the Grand Armée of Napoleon, popularized this technic and brought to military surgery some of its greatest permanent triumphs. Among other things, he performed over 200 amputations in the Borodino Campaign. Napoleon did not mention any of his generals in his will but bequeathed ten thousand francs to his chief surgeon and embellished this bequest by the statement: "to the noblest man I ever knew."

Experience has shown that all antiseptics have had their glamorous, colorful eras but

even to this day none of them has withstood the long period of trial and error. The outstanding lesson of experience is that surgery and not antiseptics is the factor that determines the outcome; it is what is taken out of the wound and not what is put into it that determines the outcome. This is because all organisms live and propagate on dead tissue and if robbed of this nutrient media they perish. This is the basis of débridement and we perform this surgical ritual properly if we are guided by three criteria, namely, we excise until the damaged area bleeds freely, it attains normal color and it contracts if muscle is involved. Thus, we have learned that excision of $\frac{1}{16}$ of an inch may suffice in one patient and yet in another many inches must be sacrificed if a surgically clean field is sought. The sulfonamides of this day and generation presumably made wide excision unnecessary but this viewpoint soon proved fallacious. At Pearl Harbor, our first proving ground in World War II, we used sulfanilamide in the débrided wound and sulfathiazole systemically for the postoperative period. In addition, we rarely performed primary suture, even though many of our casualties were operated upon within what the author long ago named "The golden period" of trauma, namely, the first six hours after injury. Primosecondary or delayed suture was the method of choice in any wound associated with bruising or severe laceration of tissue and in all fractures unless the fragmentation and soft part damage was slight. This delayed suture process means that the sutures are placed but not tied until the third day, if in the interval there are no clinical or laboratory evidences of infection. This procedure of avoiding primary suture was also a lesson derived from World War I.

In our Pearl Harbor series of operated patients the mortality was 3.8 per cent and this happy outcome was due to the early arrival of the casualties, débridement with secondary closure, the use of the sulfa drugs as indicated, liberal transfusions when necessary and adequate after-care. However, this result would not have been attained had the skill and devotion of the surgical staff been unavailable. This group of casualties at Pearl Harbor exceeded in severity any that the writer had seen in World War I during a nineteen-month period of service abroad, eight months of which were served with the French army and one month in Belgium.

The use of sulfa drugs in fresh wounds is much more restricted now and will probably be superseded by penicillin or other antibiotics, and thus the repetition of prior experience is already in process. In our efforts to obtain the sterilisia magna we pass through a cycle of caution, then a period of great enthusiasm, then enter the zone of doubt and finally end with distrust. This has happened repeatedly in many surgical fields, perhaps most notably with antiseptics; just now the leaders in the field are penicillin, streptomycin, bacitracin and others of that basic type. We are getting away from the use of all of these in or upon the wound and rely more definitely on intravenous medication

Experience now indicates that some of our failures are due to reliance upon any one antiseptic to overcome every type of infection. In reality, some antiseptics are relatively specific for a dominant type of organism and inert toward others. Hence, the prudent surgeon now seeks laboratory aid to confirm his opinion as to the prevailing type of infection, before assuming that his patient has a staphylococcus and not a streptococcus or mixed type of infection. This does not mean that clinical signs are to be ignored before beginning treatment, any more than diphtheria antitoxin would be withheld pending laboratory confirmation if there were suspicious throat signs. There is no question as to the value of penicillin and its consorts in selected cases, but these are not infallible and the high tide of enthusiasm is already on the wane in respect to their sovereign power in all wound infections. Again, let it be stated that experience asserts positively that there

is no substitute for adequate surgery skillfully performed at the opportune moment.

Wounds, not the outcome of surgical intent, are already contaminated or infected and thus are closely related to the infection problem just discussed. This contamination phase ends after the first few hours and when the six-hour, post-trauma period arrives infection is usually present to some extent. Hence, the primary care, as in so many of the traumas, determines the outcome. Experience again comes to our aid and teaches that soap and water cleansing is the best infection preventive in every type of accidental wound. This cleansing should be just as ritualistic and vigorous as the preliminary hand washing prior to a major operation. If after there are evidences of damage tissue remnants, these are removed by non-sacrificial débridement already described. Primary suture is reserved for the group seen within the golden period and in which tissue damage is minimal or removable. If in doubt, delayed suture is the preferable method; if most of the automobile and many of the industrial accidents were thus treated, the incidence of wound infection would be halved.

Tetanus and gas gangrene are relatively rare but the use of the combined prophylactic serum should be routine, if there has been an adequate source of infection and especially, if the site is in thickly muscled areas. In World War I the only indisputable surgical lesson universally accepted was the prophylactic efficacy of tetanus antitoxin. In World War II this lesson was again conceded but as yet it is too early to assess the outstanding surgical advance of this recent conflict. Perhaps one lesson will be the demonstrated value of infrequent dressings and sterile precautions to prevent re-infection while doing same.

Burns are still the source of much difference of opinion in regard to treatment. For many years the writer has defined a burn as a wound due to thermal, chemical, electrical or radiant energy sources. Viewed thus, the problem resembles that of any wound and again infection looms as a prominent factor. Gone are the days in which lotions, salves, oils, tannic acid, various dyes and a host of other remedies are applied. Instead, the days have arrived in which the aim is to cleanse promptly by soap and water, gently débride, suitably cover with sterile petrolatum or mineral oil, apply massive dressings of splint proportions and let alone for seven or more days. This, in effect, is wound treatment plus the necessary antishock fluid loss precautions. Early grafting is now a standard feature and the dermatone sheet-graft has prevented such crippling and repeated procedures.

Joint and tendon involvement with wounds again introduces the infection element and prompt operation is the initial endeavor to rob the organisms of a place to live and abound by literally a scorched-earth campaign—cleansing and débridement. Sprains are best treated by non-restrictive strapping and early mobilization versus plaster encasement and immobilization. Synovitis and bursitis are aspirated at once and gradually increasing use becomes an early and not a late feature. Activating of adjacent muscles by self-usage is an essential adjunct, especially in the knee-joint, where the writer enjoins attention again to the statement that no knee-joint is stronger than its own quadriceps. Tendon severence continues to be a major problem and to Bunnell and others we are indebted for much valuable advice, notably as to the use of removable wire sutures applied á distance. To repair tendons at the wrist is one of the major problems in traumatic surgery and in this area, as in others, experience teaches that early repair means early assured recovery. After the golden period of six hours infection often interferes and wisdom dictates a waiting period of several weeks since residual hidden infection may be stirred up by operative interference. It is definitely wiser to use silk or cotton rather than catgut in tendon repair, not forgetting that inert wire also has a place. One of the outstanding advances

is the freedom with which intra-articular traumatic lesions are now approached. This applies especially to the knee-joint cartilages and ligaments. The many ingenious operations suggested for crucial ligament damage do not find many timid souls (like the author) very enthusiastic, for the good reason that most of the crucial lesions apparently repair themselves or else associated ligaments take on their function.

The writer has never operated upon a patient with this type of injury because most of them recover without tendon reefing or other types of repair. In the arthritic group the making of a new joint with a metallic or plastic capping has been notably successful in some patients, especially in the hip-joint. The present fashion is to operate very often for intervertebral lesions on the basis of disc disturbances, not only for the lumbar but also for the cervical level. These intervertebral joints are subject to the same pathologic assaults as any other articulation and to make laminectomy the first rather than the last choice does not appeal to the author as prudent therapy. Pain in the back is due to many causes and operation should not be undertaken by the inexperienced or the occasional operator.

The diagnosis of the disc syndrome is essentially that of an intraspinous tumor; and if the neurologic symptoms are lacking, operation can be exceedingly harmful. It is not good surgery to inflict by operation a very real type of pathologic condition in an attempt to cure a suspected type of disorder. Disc disturbances can often be cured without operation, just as knee-joint discs (the semilunars) are frequently amenable to non-operative relief. The analogy between the knee and the interspinal cartilages is very close from the standpoint of causation, symptoms and pathology. Even in the experience of the best known neurosurgeons the successes do not often exceed 50 per cent, not forgetting that many times the relief by disc removal is dramatic and sustained. The experienced surgeon in this spinal area is unusually cautious in selecting his patient, knowing full well that in the compensation or legal group success may not be attained, even though the findings and the operative result might register success if this and allied medicolegal angles did not exist. Trauma incidental to the ordinary accidents of leisure or sports registers in a regular pattern, but when the responsibility for an identical mishap can be placed on some one else, the situation becomes fogged and a host of subjective complaints that rarely are actually related to the injury in question appear. Experience amply denotes that only a so-called "lump settlement" is the healing balm that often supersedes the most skillful surgical management. Morale is so often lacking in this zone of compensable injuries that the surgeon in attendance or the consultant is beset by a chain of circumstances entirely foreign to the trauma and one that presents a pathologic condition that has come to be known as "compensationitis."

Fractures and dislocations therapeutically are very much in evidence, especially the former in respect to so-called newer forms of treatment. We are again passing through a phase in which operation is given the first, instead of the last place in therapy. The gadgeter in traumatic surgery has a field day in many types of injury, but in fractures some of the recommendations resemble those that could be found in Popular Mechanics, rather than in a standard surgical treatise. There is nothing essentially new in the current models of plates, pins, screws, bars and wires because the majority of these are but streamlined modifications in use half a century or more ago. Pinning of the hip is an exception to this commentary and so is the judicious use of nails or screws, but the vice is that the use of indwelling metals is a surgical fault and negates the age-old precept that the tissues do not willingly tolerate foreign bodies. The vast majority of fractures can be managed by non-operative measures and failing this, skeletal traction is an efficient and safe procedure if any tissue invasion is

necessary. The present teaching of converting an ordinary simple (closed) fracture into a compound (open) fracture to obtain better alignment with a more or less complicated metallic device is not without danger, even in the hands of skillful proponents. Bone infection is osteomyelitis and as yet we have not passed the stage where the old adage "once an osteomyelitis, always an osteomyelitis," can be disregarded or discarded. A fracture is a wound of bone, and here again as in all types of trauma, infection is a foe to reckon with whenever adjacent covering is damaged or torn.

The author does not mean that we should cling to old methods in fractures or any other effect of trauma, but it is firmly asserted that the experienced do not operate unless other less hazardous and equally effective measures are found wanting. Complacency has no place in progressive surgery but conservatism has always been a guiding principle and should still prevail. Years ago when plating was the vogue a great many surgeons were able to report initial successes; however, the tide turned when non-union, osteomyelitis and amputation appeared with too great frequency. Already some of the vaunted current operative procedures have succumbed in the flames of the crucible of experience and others are in the process of flickering.

Anesthesia is one of the great allies in traumatic surgery and the progressive development in this phase has been remarkably consistent. Here again another specialty has been created to replace the willing but relatively incompetent service rendered by a confrere. Many of the newer anesthetic agents have passed through the stage of trial and error and now can be used with safety and accuracy. It is axiomatic in traumatic surgery that any procedure should first of all be safe and next it should be simple. The need for an anesthetic that would provide safe, complete relaxation for a short period has long been in demand. If, in addition, there were such desirable features as freedom from a stage of excitement during induction, recovery and prompt return to full consciousness without nausea and vomiting, then indeed would such an agency be welcomed. For painful dressings, incision and drainage, the reduction of fractures, dislocations and many other emergencies, a safe, easily administered agent is often demanded. Intravenous anesthesia has been the answer and now the use of pentothal has become a standard method and in many cases it is a safe agent for prolonged administration and is also useful as a preliminary procedure to inhalation methods. However, the simplicity and certainty of its application should not lull us into complete security, and at all times oxygen and coramine (or the equivalent) should be readily available.

Neurologic surgery has advanced appreciably, especially in regard to intracranial operations in which the electrocoagulation technic has measurably averted one of the greatest dangers, namely, hemorrhage.

There is no uniformity of opinion as to the feasibility of peripheral nerve transplantation but there are an increasing number of reported successes in this important sphere. The repair of a damaged spinal cord is yet beyond our reach and thus the outcome in the post-traumatic paralysis following vertebral fracture continues to be tragic. However, much is being accomplished by active rehabilitation measures in spinal as well as in other serious injuries. The principle of self-aid is now properly being stressed so that the cooperation of the patient has become a main factor. It is too often forgotten that baking, massage and other physiotherapeutic measures were originally intended only for the disabled patient; the current tendency is to provide the necessary neuromuscular tonicity by physiotherapy rather than by the cooperative activity of the patient. This process is not only habit-forming but it also lowers neuromuscular tone and general morale. The many electrical devices now employed without adequate indications add to the confusion, and this is especially so in respect to the so-called short wave and long wave

treatments; indeed, many of these are so endlessly given that they deserve the name permanent wave.

Occupational surgery has made great strides and medical men in industry have enhanced their reputation measurably, especially during the recent war years when our mechanical age was providing peak production. The follow-up available in industrial organizations provides the best in end results because the control of the patient is more definitely assured than in private or hospital practice. This branch of our profession has evolved in startling fashion and now recruits a very high grade instead of the mediocre participant who drifted into this arena because he was unsuccessful elsewhere.

This cursory review seeks to indicate that collective experience is the foundation of traumatic surgery, just as it is in every branch of our profession. Methods should and will continue to be presented for the better treatment of the injured who now comprise a very large percentage of private and hospital patients. The aviation age is here, and with it many variants of trauma are already evident and these will continue to test the skill and adaptability of those who deal with traumatology. The general practitioner is often the first line of defense in trauma and his initial treatment is often a main element in the outcome.

We must not be too prone to accept loudly acclaimed methods unless authorized by those who have earned by experience the right to act as our guides and mentors. Conversely, we must not be complacently conservative and become bound to outmoded practices. There are new models in traumatic surgery and it is our duty to accept advances if properly authenticated. The gadgets in traumatic surgery are limitless, some of them are excellent but many are of no value and occasionally are harmful. There are still many unsolved problems in trauma, even though this branch of surgery has the most ancient background of all the ancients. In the days of the pyramid builders fractures of the femur were very frequent and just as troublesome as those of our generation. Fracture of the os calcis is now probably the most common problem fracture and despite a dozen or more methods advised no treatment is uniformly applicable or successful. There is, as stated, an awakened interest in trauma on the part of all surgeons and this will continue to increase our knowledge to the end that the injured will receive a still higher grade of care and attention.

Traumatic surgery is the most generalized type of surgery, in that any section of the body may be affected by injury. For this reason a traumatic surgeon should have skill and experience sufficient to meet any emergency, inasmuch as trauma is no respecter of persons or of any anatomic zone. A fracture of the pelvis may be complicated by a urologic problem, rib fractures may be associated with intrathoracic damage and a stab wound of the abdomen may demand the skill of an abdominal surgeon. Thus, a traumatologist needs a background of knowledge and experience and be prepared to render effective aid for any emergency.

The past and the present of this subject with some of the accepted and discarded phases have been discussed and naturally a preview of the future is in order. Routine standardization probably will never be attained because of the varying circumstances surrounding severe or multiple injuries. The presence of shock and hemorrhage may negate definitive early care, as will prevailing circumstances and constitutional or age factors. A fracture of the femoral neck in a feeble octogenarian or a severe burn in a child may make it impossible to apply the routine management in the early stages. The presence of cardiorenal, vascular, diabetic, mental or other preceding disease processes may make prolonged incumbency undesirable and utterly upset a schedule indicated for the injury itself. Thus, treatment of the person takes

precedence over the treatment of the injured part and again features the diverse variants of trauma.

An outstanding need for the future is the realization that trauma is an emergency and that a broken thigh is entitled to the same immediate attention as a ruptured appendix. Every hospital should be so staffed that the injured patient is accorded the same early care now available for many types of general surgery.

Substantial progress has been made in the past decades and this fortunately applies to the 80 per cent group of injured already discussed.

As indicated, it is too early to appraise the actual war gains that may be transferred to civil practice, but the outstanding fact that the attention of so many of the profession was focused on trauma cannot fail to have lasting value. Thus, the summation of these experiences in trauma may again be said to revolve around the idea that now, more than ever, our confreres are injury conscious and alive to the needs of the victims of trauma. The postwar period is already demanding increasing plastic repair and advanced rehabilitation procedures that will be useful also in civil practice.

No injured person should be moved until his wound has been dressed and the fracture has been immobilized securely. . . . Calmness and the avoidance of unnecessary haste are important, and rough and unnecessary handling should be avoided.

From "Fractures and Dislocations for Practitioners" by Edwin O. Geckeler (The Williams & Wilkins Co.).

CAUTION IN HANDLING THE EXTENSIVELY INJURED

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THE development of high powered machines, work at heights and in depths, have increased the magnitude of injuries both in gravity and multiplicity. Knowledge of methods of treatment and laboratory control has been improved so that persons with severe injury can sometimes be saved who would formerly have died. The human being cannot stand unlimited trauma. With the extensively injured no rules can be laid down to cover all cases, but there are certain principles to guide us in doing first things first, thereby not adding surgical trauma until it can be tolerated and not delaying reparative surgery until the progress of infection becomes more than the body can cope with.

We are presented with a patient with a definite serious injury which demands our attention. Is this the only injury he has or even the most important one? A few minutes spent in trying to learn the mechanism of accident may save the patient's life. A fall in an elevator may result in fractures of the os calcis, above ankle or at knee, the vertebral bodies or the base of skull, or any or all combined. The os calcis fracture is evident, but to disregard the other possibilities may mean that a simple compression fracture of the lumbar spine will produce a cord injury, possibly irreparable, in moving the person to or about the hospital. If the mechanism of accident has been such that severe injuries may have been produced, treat this patient as though these injuries have occurred until it has been possible to examine him thoroughly enough to rule them out.

Suppose a person's trunk has been caught between the rear end of a truck and a wall, or by a rock fall in a tunnel. He is dazed but not in too bad shape. Ribs may have been broken puncturing pleura and lung, intercostal vessels may be bleeding internally, anything may have happened within or surrounding the abdominal cavity, including spinal injury. There may be little sign of anything definite when first seen, but the mechanism of injury has been such that it would seem that severe injury should have resulted. Handle him as if this is the case until all severe injuries can be ruled out following various tests at a time he is able to stand them. Protect the patient from all further trauma until possible injuries have been disproved rather than consider that he was fortunate not to have been hurt worse. If a history is obtainable from the patient or bystanders, this history may mean using a few moments which will save life. Also remember that while stories of sudden occurrences may often vary greatly, still they may give an idea of what might have happened.

Ambulances are rarely manned with doctors. It would be a waste of trained man power if they were. By the same token it is a public responsibility to insist that ambulance crews of all types—morticians, private ambulances, police and fire departments, industrial, hospital—shall have the minimum training of a Red Cross First Aid course. For the extensively injured person this amount of training may make all the difference between life and return to employment or permanent disability or death. If speed of the ambulance only is the first consideration the border line case will usually be lost anyway.

Is there possibly an injury to the cervical or lumbar spine? If there is, an unparalyzed patient may be and often is converted into a completely, permanently paralyzed person merely by the method used in first lifting him from the ground. It is inexcusable for an ambulance crew to be unaware of the safe method of transporting possible spine injuries. The injured person is bleed-

ing from an extremity. Shall a tourniquet be used? Indications for it are readily learned by any layman. Improper use, or less commonly failure of use, may make the difference between life and death. Traction splinting of lower extremity fractures at the site of accident may lessen the amount of shock in the person with multiple injuries just enough to turn the tide between a dead and live patient later. With over a million accidental injuries annually, 150,000 doctors cannot be present when they happen. We should be responsible for knowing that the ambulance situation in our own community is covered by persons with at least a minimum of training.

The method of examining the extensively injured is of great importance to him. If not in shock, the patient probably will be in a short time. Do not wait for the blood pressure to fall before instituting shock treatment as this is a sign that shock is already far advanced. Give morphine to relieve pain, except in brain injuries, and give enough to relieve it. If he is cold, warm him up and keep him warm, but this does not mean piling on hot water bags and blankets until he is bathed in sweat and losing precious fluid. He needs a transfusion. Obtain the blood and cross matching at the earliest moment, but have plasma running in the meantime. This will help prevent or relieve shock and will not waste time getting a needle into a vein when blood is ready. Remember whole blood is the fluid really needed in traumatic shock, except from burns, whether there has been evidence of loss of blood or not. Administration of too much fluid can be as dangerous as too little. Frequent checking of the specific gravity of the blood or the hematocrit is needed to furnish the right amount.

Hemorrhage must be stopped. Proper pressure application is almost always sufficient for external bleeding. Preventing further bleeding is nearly as important as replacing the blood lost already.

Shock and hemorrhage must be considered first. Further treatment cannot be rendered except on a live patient. Next and accompanying it as far as possible is the physical examination. It must be gentle and without undue exposure in order not to increase shock. Which are the immediately important fractures? Is there a possible abdominal or chest injury? With signs of possible abdominal injury we must consider the solid organs, liver and spleen, the hollow viscera with possible perforation, the blood vessels, e.g., mesenteric, the retroperitoneal organs—kidney, adrenals, retroperitoneal hematoma, spine and spinal cord, perforation of the diaphragm, etc. We must decide whether any operative procedure is indicated at the first possible moment, which part of the body will be approached first when the condition improves sufficiently to do anything, whether no marked improvement can be expected in the general condition until some intervention has been accomplished even if the person dies in the attempt. These decisions may need to be changed as the condition changes, but we must constantly keep in mind doing first things first. There is no use applying skeletal traction for a fractured femur and spending time carefully arranging traction suspension when we believe the abdomen must be explored at the earliest possible moment, requiring the taking down again of the traction apparatus. Rather keep the part in emergency traction until decision is made regarding the abdominal trauma.

X-ray examination is often carried to a ridiculous extent. What films do you absolutely need to determine what you will do to the patient first when possible and what will prevent further injury in the meantime? Demonstration of free air below the diaphragm may prove rupture of a hollow viscus. Examination for this is of little use unless the patient is in the upright position. The presence of a vertebral column injury may need to be proved before the patient can be supported in the sitting position without danger of spinal cord damage. However, the use of a tilt table allows the examination for free air without endangering the spinal cord.

Too many early *x*-rays of the skull are taken. Unless the patient is cooperative enough to keep his head quiet, these should be postponed unless one believes it is absolutely necessary to determine the presence of a compound depressed fracture or a fracture at a site which could readily produce an injury to the middle meningeal artery. Otherwise no operative intervention on the skull is going to be instituted early anyway and *x*-rays for the record may better be done later.

The presence of fractured ribs proved by *x*-ray will usually make little difference in early operative treatment. There may have to be treatment for pain on breathing, for tamponade of the lungs with blood, for paradoxical respiration or tension pneumothorax, but time and effort spent on *x*-ray of the chest offers little in the early care of the extensively injured that can not be learned equally well or better by the physical examination. Anesthetizing the proper intercostal nerves may often change the picture entirely in a patient suffering severe chest pain.

Beds in the admission ward are a practical necessity in these cases. Close supervision is necessary. Many patients suffer further injury and exposure in non-medically supervised movement from stretcher to *x*-ray table, ward bed or operating table. For an orderly to undress a patient behind a screen often constitutes an acute danger. It is better to cut off a good shoe than to make a simple fracture of the leg compound in attempts to pull it off. Coats and pants are much better cut for removal if movement might in any way endanger the patient. Critical time is lost in moving to a ward, etc., which should be employed in getting plasma and blood into a vein. Do not be satisfied with *ordering* fluids but *know* that they are commenced immediately.

With fluid running and the advisable amount of preliminary examination completed, orders must be written so that assistants may be certain of the sequence in which they are to carry out examinations and treatments. With no traction applied before coming to a hospital, naturally fractures requiring immobilization in emergency traction should have this done before plaster immobilization is applied to other fractures. If you wish pulse and blood pressure recorded every fifteen minutes or half hour, see that some one is delegated to do this without making a doctor temporarily discontinue a more specialized part of the treatment. In an unconscious patient does your order for urine specimen mean when he becomes conscious and voids voluntarily, attaching a container for involuntary voiding, or immediate catheterization to learn whether there is difficulty in passing a catheter into the bladder or if the urine is full of blood or sugar? You examined the patient and your order must be framed so that your assistant has some idea of its immediate importance and what you are looking for. There is nothing rational in ordering for the extensively injured patient *x*-rays of all bones which your examination shows might possibly be fractured and not stating which, if any, must be done immediately to guide treatment at the moment. Do not expect the *x*-ray technician to read your mind or ask him to kill the patient by taking immediate pictures of most of the body. It must be your decision whether an *x*-ray finding may change the treatment in the next few hours for this critically injured person or whether he should be disturbed as little as possible.

Wounds should be cleansed, excised if indicated, and sutured as early as practical. Much loss of time and possible infection will be saved to the patient if he gets well, but this work must not endanger his life further by increasing shock or taking an assistant from more necessary procedures.

Hemorrhage must be stopped and an open chest wound closed immediately. Evidence of intra-abdominal perforation calls for operation as soon as the general condition is improved sufficiently to stand it. Otherwise there are few conditions that require operation until recovery from shock

seems quite definite. With sufficient help in the form of operating teams and trained laboratory assistants to handle the need for and introduction of fluids, operations can often be done much earlier keeping shock under control during the procedures rather than knocking a person down again by operation as soon as he has recovered from shock the first time. This is only true where a large trained personnel is available and a special shock team takes entire responsibility for the general condition of the patient.

Many details of treatment or examination make much difference in the survival of these patients. Some examples follow: Most cerebral injuries show some lack of oxygenation from respiratory depression. It is advisable to commence oxygen inhalation in all patients unconscious from trauma. With a cerebral injury and unconsciousness, but no evidence of injury to the gastrointestinal tract, a Levin tube through the nose from the first can supply the needs of fluid and nutrition largely rather than continuing intravenous therapy over a number of days. It is too often forgotten that unconscious patients are likely to starve to death. If a foreign body is projecting from any part of the body, do not remove it until the operating room is ready and the patient is in shape for operation. Too often the foreign body is plugging an injury in a large vessel with danger of fatal hemorrhage on removal unless all is ready to stop it. Abdominal paracentesis, when positive for blood or air, may be the simplest method of making a decision that abdominal exploration is necessary at the earliest possible moment. Formerly if one was fairly certain of a diagnosis of rupture of the liver the abdomen would not be opened for this reason only. As soon as the peritoneum was opened and intra-abdominal pressure released, hemorrhage was likely to start up so severe that death occurred before the wound in the liver could be sufficiently plugged with gauze. Now with the introduction of non-absorbable coagulant material and massive transfusion rupture of the liver should be handled in the same way as hemorrhage elsewhere. Never forget that evidence of a ruptured spleen may not appear for several days after injury. It must always be kept in mind when there is possible trauma to the lower thorax and upper abdomen.

Blood in the urine may come from any part of the urinary tract from kidney through urethra and in contrast there may be a clear urine with a complete rupture of the ureter at any point from the pelvis of the kidney to the bladder. In general, injuries to the kidney should be treated conservatively and non-operatively whether simple contusions or fragmented kidneys. An intravenous pyelogram is often of great value in determining fairly early the extent of the lesion. On the other hand rupture of the bladder or urethra requires radical operative treatment as early as possible before infection sets in. An intravenous pyelogram is much safer, if the diagnosis cannot be made otherwise, than any injections of opaque substances or air through the urethra.

Rectal injuries with possible perforation demand early colostomy as the most conservative procedure. Arterial spasm in any severe injury of the extremities is common and evidence of this must be watched for and often relieved by paravertebral block. A procedure, such as open reduction and internal fixation of a compound fracture, might be advisable if this is the only injury, whereas in multiple injuries it might be foolhardy from time consumed or from the danger that infection may set in in some of the other injuries and later affect the fracture site through the blood stream; conversely, other injuries may be of such a nature that it appears absolutely necessary not to immobilize the extremity and internal fixation becomes advisable in spite of the danger of infection. If a person has been in the Armed Forces since the beginning of the last war he should be given 1 cc. of tetanus toxoid for any open injury, not antitoxin. It is safe to assume that he had his original injections and his

booster dose after one year. It is considered that for at least five years thereafter any injury requires only another booster dose. Severe reactions to tetanus antitoxin are common, so toxoid should be used when the person has been recently immunized. When there is occasion to administer considerable amounts of glucose, remember it is useless if spilled in the urine and should rather be covered with the use of insulin. A person not receiving food by mouth can be kept alive as far as nutrition is concerned almost indefinitely with intravenous protein hydrolysates, glucose, fluid and vitamins. The person with extensive injuries needs two to five times as much protein intake as the normal and will not do well without it.

SUMMARY

The extensively injured need to be handled in a different manner from the person with a single injury of lesser degree. On account of more marked shock every effort must be made to protect them from increasing this and to combat it promptly. Since they will not tolerate too much being done at once great judgment is needed to do "first things first." Possibly one's main interest is centered in a particular field of surgery. One must not become too engrossed in treating one part and forget the whole man. Organization and team work are required if such persons are to be given the best chance. The importance of history, transportation, treatment of shock and hemorrhage, thorough, brief and non-traumatic physical examination is reviewed. Instances of detailed care of parts so that the whole man can be reconstructed promptly are cited. More of these patients will be saved if caution is used in the amount done, keeping in one's mind the order of importance of the various problems. If an operation is necessary all efforts must be exerted toward getting the patient ready for this at the earliest possible moment. Meantime the less acute injuries may not be neglected, lest complications set in which will make these the last to get well.

ROENTGENOLOGY OF THE SPINE IN INDUSTRY

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THE interest of the industrial surgeon in the spine centers on traumatic lesions, structural weaknesses and post-traumatic conditions which will be discussed in the following order: (1) Fractures and dislocations; (2) invisible traumatic lesions; (3) (post-traumatic conditions) and (4) roentgen demonstration of vertebral abnormalities.

FRACTURES AND DISLOCATIONS

Dislocations in the spine are usually accompanied by fractures. The roentgen features by which these conditions are recognized are altered relation of parts for dislocations and, for fractures, changes in shape or size of vertebrae, displacement of fragments, solutions of continuity and, later, development of callus.

Compression Fracture. Most fractures in the spine are of the compression type. They may be produced quite easily, especially in older people. Merely lifting a heavy object may be sufficient trauma to fracture a vertebral body. Sudden flexion of the spine is also an adequate force, and falls in which the patient lands on the feet, knees, buttocks, back or head readily result in compression fracture of vertebrae.

Such fractures should be looked for after any such trauma if there is localized pain in the back and even when there is no complaint of back pain if other parts are injured which may distract the attention of the patient away from the spine as, for example, when a calcaneus is fractured by landing on the feet or when there is multiple bruising in a rolling fall, as from a horse.

Compression fractures are usually single but may occur in widely separated portions of the spine. For this reason, the entire spine should be examined when compression fracture is present. If more than two vertebrae appear fractured, the possible presence of a pathologic fracture should receive special consideration. However, the pathologic conditions most commonly leading to multiple compression of the vertebral bodies, such as malignant tumor or post-menopausal osteoporosis, occur at an age which is beyond the usual age of industrial patients.

Shape of the Fractured Vertebra. Compression of the body of a vertebra by fracture usually produces a characteristic deformity (Fig. 1) which is the chief means of differentiating compression fracture from other lesions roentgenologically. Typically, only one-half of the vertebral body is affected, usually the superior half. The fracture line extends from the superior posterior angle of the vertebral body to a point on the anterior surface slightly above its middle. There is increased density along this line in the fresh fracture due to impaction of the fragments. The superior surface is broken anterior to its middle, forming an anterior and a posterior fragment. The anterior fragment is less depressed anteriorly than posteriorly. This causes angular concavity of the superior surface with the apex of the concavity at the junction of the fragments. The anterior fragment is forced slightly anteriorly relative to the inferior portion of the vertebra and thus forms a slight projection in the anterior surface of the vertebra at the anterior end of the fracture line.

These features, the fracture line, the impaction, the superior surface and the anterior surface are characteristic for compression fracture individually and collectively. The deformity persists and is still characteristic after union and thus enables differentiation of old compression fractures from other deformities.

In post-menopausal osteoporosis with

spontaneous collapse of vertebral bodies deformity of the vertebral body is usually multiple and progressive. The anterior surface of the body appears intact. Superior and inferior surfaces are excessively concave but the concavity is rounded not angular. The intervertebral disks are correspondingly more rounded and deeper; they approach the spherical shape. The vertebrae are undercalcified. The patient has passed the menopause (natural, artificial or pathologic). Of course, additional traumatic compression fracture may occur with slight injury in this condition and add the features of compression fracture to the other changes.

Shallow biconcave vertebral bodies in chondrodystrophy present no angular deformity of the horizontal surfaces and no projection in the anterior surface. The shallowness is notable throughout the vertebral body and many vertebrae are about equally involved.

In the case of tumor the vertebral body is decreased in density or contains rounded areas of increased density. Areas of bone destruction and soft tissue mass may be visible. Fracture may occur and add the typical features of compression fracture to the other changes.

Usually the residual of adolescent wedging round back ("epiphysitis") is multiple and confined to the dorsal region. Both the upper and the lower halves of the vertebral body are usually involved in the wedging. The superior and inferior surfaces of the body are intact and not excessively concave. The anterior surface presents a dimple at the central plane of the body and there is no projecting fragment in its superior half.

A moderate degree of wedging may have developed anteriorly in the dorsolumbar area or posteriorly in the lowest lumbar vertebra in normal spines. This may be somewhat exaggerated in residuals of ricketts or localized chondrodystrophy. In these conditions the deformity of the anterior and superior surfaces typical of compression fracture is completely lacking.

Fig. 1. Compression fracture of a vertebral body. This case exaggerates and therefore emphasizes the characteristic features of the deformity.

This also applies when a vertebral body has become wedged by growth disturbances in connection with fused ribs or incomplete segmentation of the vertebral bodies.

The anterior and the horizontal surfaces are convex in hemivertebra rather than concave and lack the characteristic deformities of compression fracture. The anteroposterior diameter of the body is short. The intervertebral disks and adjacent bodies are deformed to conform to the shape of the affected vertebra.

Size of the Fractured Vertebra. The vertical diameter of the vertebral body is decreased anteriorly in compression fracture but the horizontal diameters may be increased. These changes are not diagnostic for fracture but are mentioned to contrast them with some other conditions. In all of these other conditions the characteristic shape of a fractured vertebra, which has been described, is lacking.

In Paget's disease and benign tumor all the diameters of the vertebral body may be increased but there are decreases of density or variations in density or texture which are foreign to fracture.

The vertical diameter of the vertebral body in chondrodystrophy is narrowed but the horizontal diameters are increased.

FIG. 2. Accessory ossification center at the anterior superior angle of the vertebral body. The junction with the body has been traumatised causing production of post-traumatic calcification inferiorly.

The whole of the body is affected and most of the vertebrae show about the same degree of change.

The anteroposterior diameter of vertebral bodies may be broadened by developmental influences. Examples are found in the superior surface of the sacrum in spondylolisthesis and in the inferior surface of the fifth lumbar vertebra in posterior prominence of that vertebra. In these conditions neither the anterior nor the horizontal vertebral surfaces show the deformity of compression fracture. If there has been resorption of the anterior angle of the sacrum in spondylolisthesis, the superior surface of that vertebra is convex not concave. The increase of the anteroposterior diameter in these conditions occurs during the years of growth. In legal cases, the increased diameter of the superior surface of the sacrum in spondylolisthesis may be used as positive evidence that the condition dates back to childhood.

Other Fractures. Fractures other than compression fractures are to be recognized roentgenographically by the diagnostic characteristics of fracture lines and of fracture fragments and by displacement of fracture fragments. Not all fractures are recognizable. Many fissure fractures, especially in the coccyx, the sacrum and the vertebral arches cannot be seen in the roentgenogram even though surgery or autopsy has demonstrated their position. In this connection two facts become particularly important: First, one must never assume that there are no invisible fractures in the arch of a vertebra which may endanger the patient if surgery or reduction of a compression fracture are to be attempted. Second, further roentgen study of the spine should always be planned if it is important to identify, for legal or other reasons, all of the fractures which may be present in a given spine. Additional views from new angles may reveal a fracture previously invisible. Resorption along a fracture line may cause a fracture previously invisible to become visible in four to six days. The development of visible callus in three or more weeks may yield evidence of a fracture previously invisible.

Fissure Fractures. The diagnostic characteristics of a fracture line serve to identify fissure fractures and may also be used to confirm the interpretation in fractures with separation or displacement. The fracture line is to be distinguished from the developmental division (cartilage line) but it should be mentioned in passing that the developmental division may, of course, be traumatized. Such traumatism may be suspected if the surfaces of the cartilage line are far from parallel to each other and may be regarded as demonstrated if visible callus appears at the margins of the cartilage line in a few weeks. (Fig. 2.)

The fracture line is a line of division in bone at which the bone surfaces are spiculated (if fresh) and irregular, the width of the line is irregular and the margins of the line are angular.

The cartilage line is a line of division in bone at which the bone surfaces are smooth and regular and the width of the line is approximately equal throughout with its sides parallel to each other and the margins of the line are rounded. Several of the conditions in which the cartilage line is seen will be mentioned after the discussion of the size of fracture fragments.

Size of Fracture Fragment. The important point about the size (and, to some extent, the shape) of a fracture fragment is that it should fit the defect in the bone from which it has been separated. If one imagines the two pieces of bone to be fitted together, a bone of normal size and shape should result. In contrast to this, it is almost universally true that an accessory ossification center presents not only a division of bone but also a greater quantity of bone than would normally be present. If one imagines the ossification center to be fitted to the main body of the bone, the resulting mass would be larger than a normal bone and would vary from the normal shape. Consideration of this fact, together with the presence of a cartilage line, serves to differentiate accessory ossification centers from fissure fractures.

Conditions in which a cartilage line or an accessory ossification center are present include the following: (1) Spina bifida: some bone is lacking (the spinous process). If the space between the laminae is small, the line of division is a cartilage line. (2) Free spinous process: some bone is lacking;—the spinous process is represented only by a rudimentary ossicle which is sometimes mistaken for a fracture fragment. The laminae are not united to the rudimentary spinous process. The space between the lamina and spinous process may be wide as in spina bifida but if it is narrow the line of division is a cartilage line. This condition is common at the lumbosacral junction. (3) Failure of union of a pedicle to the body or of a lamina to the spinous process or to the pedicle: The defect is a cartilage line. At the first cervical vertebra such defects may be difficult to see with sufficient clarity to distinguish clearly between the cartilage line and the fracture line. Underdevelopment of bone adjacent to the defect may be sufficient to suggest the developmental nature of the condition. More often, absence of swelling of the soft tissues anteriorly as outlined by air in the pharynx may be relied upon to indicate that the lesion is not a fresh fracture. Swelling of the soft tissue in that area regularly follows fracture or dislocation in the upper cervical spine.

(4) Bilateral failure of union of the laminae to the pedicles: This is the defect which permits spondylolisthesis. It is most common at the fifth lumbar vertebra. Forward slipping of the vertebral body increases separation at the defect and motion between the separated parts is a chronic irritant which results in irregular resorption and deposit of calcareous matter. Consequently, the defect may not clearly have the appearance of either the fracture line or the cartilage line. When the condition is sufficiently advanced to cause this difficulty it has had other effects, such as underdevelopment of the vertebral arch and increase of the anteroposterior diameter of the body of the first sacral vertebra, which identify the condition as a developmental lesion and distinguish it from fracture.

(5) Rudimentary rib: The twelfth dorsal or first lumbar vertebra frequently bears a rudimentary rib. The line of division is a cartilage line which is usually somewhat rounded with the convexity laterally. The vertical diameter of the rib is usually greater than that of the adjacent portion of the transverse process. Cervical ribs are rarely sufficiently rudimentary to be confused with a fracture fragment except in the age period from three to six years. Most of these are temporary but if they remain divided from the transverse process at the

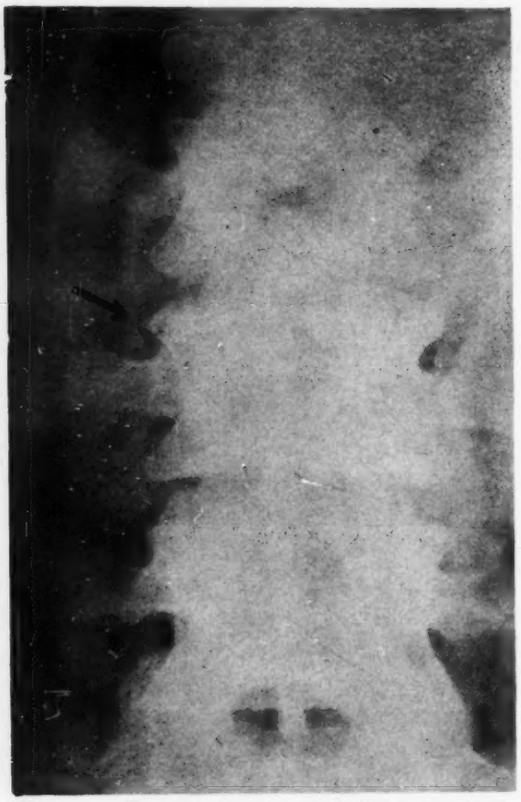

FIG. 3. Post-traumatic arthritis. A single vertebra exhibits calcareous lipping at the margin of the disk.

age of eight years they will persist. In them, the line of division is a cartilage line.

(6) Accessory ossification center at the tip of a vertebral facet: This is most common in the mid-lumbar region and at an inferior facet. The line of division is a cartilage line. The size of the facet, including the accessory center, is usually larger than normal as judged by neighboring facets.

(7) Accessory ossification center at the angle of a vertebral body: This usually affects the anterior superior angle of the vertebral body and is most common at the fourth lumbar vertebra. It is often mistaken for fracture. The line of division is a cartilage line. In whatever way the ossicle may be imagined to be fitted to the vertebral body, the resulting vertebral outline would be larger than normal and would vary from the normal shape. If traumatism has sprung the cartilage line (in this or other anomalies), callus may appear in a few weeks at the margins of the cartilage. Such callus is illustrated in Figure 2. The callus is evidence of the traumatism.

(8) Double hemivertebra: In this instance, the two portions of bone together do not equal the size of a normal bone. The line of division is a cartilage line. The bone margins are much rounded. Adjacent bones are somewhat deformed to conform to the deformity.

(9) Osteophytes: In chronic arthritis, osteophytes may be formed which are not continuous with the vertebral body and such formations may be mistaken for fracture fragments. There is no visible defect in the vertebral body from which a fracture fragment could have been derived. The supposed fragment cannot be imagined to be fitted to the vertebral body in any way which will yield a vertebra of normal size and shape.

(10) Calcification or ossification in the interspinous ligament: When such ossicles occur at the ligamentum nuchae they are not infrequently mistaken for fracture. There is no defect in a spinous process from which a fracture fragment could have been derived. The ossicle cannot be added to the spinous process to form a bone of normal size and shape.

Displacement of Fracture Fragment. In contrast to the accessory ossification center, the displaced or separated fracture fragment is derived from a bone of normal size and shape and can be imagined to be refitted to that bone to restore normal size and outline. If the defect from which the supposed fracture fragment is derived is not visible, it may be sought in additional views from new angles. If it still is not evident, the diagnosis must be regarded as uncertain; if the fragment is more irregular than an accessory ossification center and presents no cartilage line, it may be calcification following an ancient strain or healed fracture instead of a fresh fracture fragment.

Fracture fragments may be derived from the vertebral body in several ways. The fragment at the anterior superior portion of the body in compression fracture

has been described. Vertical split of the body may form large fragments. A portion of the apophysis may be elevated from the body by avulsion anteriorly by extension, posteriorly by flexion.

The most commonly visualized fracture in the vertebral arch is the fracture of a transverse process by avulsion. The spinous processes are subject to fracture by avulsion and by direct violence. Compression fracture may be accompanied by horizontal fracture across the posterior portion of the arch with vertical separation of the fragments. Other fractures in the arch are more difficult to see and many of them may be invisible. Careful inspection should be made for possible displacement of a fragment into the neural canal where it may have caused damage to the spinal cord or be a potential danger to the cord if manipulation is to be attempted. Oblique views may prove very helpful in this inspection.

Fracture Dislocation. Fracture dislocation is not a uniform entity but rather a combination of some fracture with an evident dislocation or of some degree of dislocation with an evident fracture. In the presence of the one condition, evidence of the other should be sought.

In the dislocation of one vertebra on another the displacement is often facilitated by fracture of the facets of the inferior vertebra. Careful inspection, especially with the aid of oblique views, will prove that the facets are not intact. When the facets are intact there is often fracture at the anterior superior portion of the inferior body by compression or by avulsion. Fracture of the odontoid process often accompanies dislocation of the first on the second cervical vertebra. A small chip fracture produced by avulsion is often present at a sacrococcygeal dislocation.

When dislocation accompanies fracture involving a vertebral body the posterior superior angle of the inferior body may encroach upon the neural canal and lie in close relation to the laminae of the superior vertebra. This close relation should be looked for as it constitutes a source of injury and compression of the spinal cord and a danger in the event of attempted manipulation.

In compression fracture the spinous process of the affected vertebra is separated from that of the superior vertebra toward its tip by flexion. With this relation of spinous processes there may or may not be dislocation but with any other relation of spinous processes fracture dislocation should be present. The superior facets of the inferior vertebra may be fractured or there may be fracture in the arch of the superior vertebra. If a normal relation exists between the spinous processes of the fractured vertebra and the next superior vertebra but the spinous process of the second superior vertebra is separated by flexion, there must be fracture in the arch of the middle vertebra with anterior displacement of the body even though the fracture cannot be seen.

A somewhat similar situation is seen in spondylolisthesis although the lesion is developmental rather than traumatic. The spinous process of the fifth lumbar vertebra maintains normal relation with the sacrum (except that this process is underdeveloped) while the spinous process of the fourth lumbar vertebra is displaced forward accompanying its body and the body of the fifth lumbar vertebra.

Dislocation. Dislocation of a vertebra is usually accompanied by fracture as discussed under fracture dislocations. Dislocation without fracture is usually an anterior dislocation of a vertebra on the next inferior vertebra. It requires that the inferior facets of the superior vertebra shall have ridden upward and forward over the superior facets of the inferior vertebra. Oblique views may aid in demonstrating that the facets of the superior vertebra rest anterior to those of the inferior vertebra. This position of the facets encroaches visibly upon the space occupied by the nerve roots and may bring the posterior superior angle of the inferior vertebra in abnormally close relation with the laminae of the superior vertebra with consequent

pressure upon the spinal cord. Also, the position may cause locking of the facets, preventing reduction of the dislocation.

The arch of the dislocated vertebra being intact, the tip of the spinous process is displaced anteriorly in relation to the spine of the inferior vertebra.

Developmental spondylolisthesis differs from these features. The facets do not override and the spinous process does not move forward with the displaced vertebral body. Also, the arch of the affected vertebra is usually underdeveloped.

At the sacrococcygeal joint there are neither facets nor spinous processes. Severe angulation between the sacrum and coccyx is frequently developmental so angulation alone is insufficient evidence of dislocation. There must be abnormality of the space occupied by the sacrococcygeal intervertebral disk with the space much wider posteriorly than anteriorly or the anterior surfaces of the coccyx and sacrum must be out of line. Displacement of the coccyx is usually anteriorly but may be posteriorly. Lateral displacement is very rare.

Anterior subluxation of a vertebra, particularly a lumbar vertebra, occurs without fracture or dislocation in chronic arthritis. It is not common in industrial practice because the age group involved is older. Thinning of cartilage and other arthritic changes at the facets allow forward slipping of the vertebral body up to about ⅜ inch. The vertebra being intact, the spinous process moves forward equally with the body in relation to the inferior vertebra. There is no overriding of the facets. Cartilage is visibly thinned at the facets and intervertebral disk and there are irregular arthritic calcareous deposits about each of these sites.

Rotary subluxation is said to occur in the mid-cervical area. Such cases may represent merely a combination of a strain and a protective posture. To be classed as a subluxation, the vertebral posture should not be attainable within the range of motion of a normal spine. Such a degree of displacement does not seem to be clearly demonstrated in these mid-cervical cases.

Rotary subluxation or dislocation of the first on the second cervical vertebra is usually spontaneous following inflammation in the throat. It is most common in children but may occur in young employed adults. The characteristic roentgen feature of this condition is seen in a view through the open mouth with the chin directly forward and the sagittal plane of the head perpendicular to the film. In this position, the spinous process of the second cervical vertebra, the center of the body of the same vertebra and the point of the chin are normally all in the midline of the cervical spine. In the rotary subluxation, the spinous process of the second cervical vertebra appears out of line to one side of the midline and the center of the body of the same vertebra is out of line to the other side, the side on which the rotary displacement of the first cervical vertebra is anterior.

Reduced Fractures. Reduction of the deformity of compression fracture of a vertebra by hyperextension results in an alteration of shape of the compressed vertebral body which is optimistically regarded as restoration of normal form. As a matter of fact, the deformity in the posterior and the inferior three-fifths of the vertebral body is essentially unchanged. The result of the hyperextension is simply that the fragment at the anterior superior angle of the affected body is pulled upward separating it from the inferior portion. This leaves a fairly extensive space between the fragments which must become filled with strong callus if the position is to be permanently maintained. The callus seldom becomes strong enough soon enough and much of the apparent correction is usually lost. In any case, the actual permanent improvement of deformity achieved by hyperextension cannot be determined until many months after all support has been removed from the spine.

Some of the sources of error in estimating

the amount of correction of deformity obtained by hyperextension are: Failure to observe the condition of the posterior portion and superior surface of the vertebral body; failure to allow for magnification of the vertebral shadows under the conditions of examination in hyperextension (if the height of the vertebra anteriorly is only 60 per cent of the height posteriorly the vertebra is still compressed 40 per cent no matter how much bigger it appears); failure to allow for difference of centering at different examinations (reliable conclusions are drawn only from similar examinations) and failure to follow the case a sufficient length of time to establish the permanent result.

United Fractures. The deformity of compression fracture, previously described, remains characteristic after healing and serves to distinguish the residual of previous fracture from other conditions. This is still true even though correction by hyperextension has been attempted; deformity of the superior surface remains characteristic.

Development of visible exuberant callus in three to eight weeks confirms the diagnosis of recent fracture, establishes the diagnosis of fracture which was previously doubtful or indicates the site of fracture which was previously invisible. Roentgen observation should be continued in doubtful cases for these reasons.

Ankylosis of vertebrae may occur at a fracture or dislocation. The calcification begins to develop in one to three months. If such calcification has not begun within that time, it cannot be expected to become sufficiently strong to ankylose the vertebrae firmly. When ankylosis is thought to be essential for stabilization following reduction of fracture or dislocation, delay in the appearance of the calcification suggests the necessity to look for some other means of stabilization such as surgical fusion.

Judgment of strength of union at a fracture (or surgical fusion) in the spine is a very difficult matter. The most important factor is experience. Of the visible factors, the most reliable are increasing density of exuberant callus seen tangentially, decreasing sharpness of definition of the surfaces of fragments and increasing calcareous density in the spaces between fragments. When these changes have progressed to a marked degree the union is probably as strong as it will ever be until toughened by free use. An additional difficulty arises in the matter of callus occupying a space which is subject to weight thrust, such as the space between fragments at a compression fracture after correction by hyperextension. In such spaces the callus probably rarely becomes sufficiently strong to meet the weight thrust until it is toughened by use. One must, therefore, always be prepared to see some loss of correction on beginning unsupported function no matter how long support has been maintained.

A consideration which is particularly useful in judging the presence of union in surgical fusion is the fact that all corresponding parts of the fusion tend to act in the same manner if union is developing properly. The presence of an area which is not doing as well as the rest of the fusion in the matter of decreasing sharpness of definition and increasing density between fragments is strong evidence of the probable presence of pseudoarthrosis.

INVISIBLE TRAUMATIC LESIONS

It has been mentioned that there are many fractures in the spine which are not visible in the roentgen film and that some of them may be recognized in later examinations by reason of development of callus or of resorption along the fracture line while others remain forever invisible. There are several other conditions which are not directly visualised but, nevertheless, deserve roentgenologic discussion.

Protrusion of an Intervertebral Disk. Posterior protrusion of an intervertebral disk into the neural canal is not directly visible in the roentgen film but it may be outlined by injecting opaque material into the neural canal and causing it to flow up or down the canal by tilting the patient. The

technic is too well known to require discussion here. It suffices to say that the opaque material which gives the most clearly defined visualization is lipiodol; that the prone and oblique prone positions are most apt to demonstrate the defect; that the probable presence of posterior protrusion of an intervertebral disk is indicated when the lipiodol, under fluoroscopic control, cannot be made to enter a rounded area on one or both sides of the neural canal at or just above the level of an intervertebral disk; and that the lipiodol should be removed by aspiration at the end of the examination.

The posterior protrusion of an intervertebral disk is often identified in the lumbar region but doubtless exists much more often than it is even suspected in the cervical area. It is rare in the dorsal spine. Its presence may be suggested by thinning of an intervertebral disk, but actually there is little relation between thinning of a disk and its posterior protrusion.

The roentgen appearance of Schmorl's nodes is more or less well known. There is an area in the superior or inferior surface of a vertebral body, usually just anterior to its middle, at which bone does not extend so far peripherally as it does in the remainder of the body; there is a defect, or absence of bone, adjacent to the disk. The sides of the defect may be vertical rather than slanted and the floor of the defect tends to be flat rather than rounded. Such a defect is a developmental failure of bone formation, not a traumatic protrusion of the intervertebral disk into the vertebral body.

On the other hand, there are some cases in which a Schmorl's node is present when there is also thinning of the intervertebral disk and, in that very area, stiffness of the spine and ache or pain on motion or standing. Symptoms can be completely eliminated in these cases by surgical fusion of the two vertebrae adjacent to the thin disk. These cases suggest the possibility that injury has caused traumatic protrusion of the disk through the weak area at the developmental defect (Schmorl's node) into the vertebral body with accompanying thinning of the intervertebral disk.

Protrusion of an intervertebral disk into the vertebral body also occurs with compression fracture but the protrusion is not visualized in the roentgen film and it is, at most, only a minor incident in the fracture.

Contusion. Contusions of the exposed portions of the spine are usually evident clinically and are invisible in the roentgenogram. They do not concern the roentgenologist except for the demonstration of the absence of visible fracture. Contusions may also occur indirectly by impact of bone on bone or intervening tissue. Some of these contusions have roentgenologic aspects.

Contusion of spinous processes by extension occurs especially in the lumbar area. The spinous processes are often so developed that there is little space between them. Sudden extension of such a spine may cause contusion of the tissue between the spinous processes with pain and tenderness localized at the point of injury. The contusion cannot be visualised but the close relation of spinous processes which predisposes to contusion can be demonstrated and visible fracture can be eliminated. A typical injury for the production of such a contusion is hyperextension at the moment of impact on the water in diving.

Many years ago a popular explanation for aseptic necrosis in various parts of the body was that contusion of the bone could cause petecchial hemorrhages within it which led to bone resorption. This is certainly not the usual cause of aseptic necrosis; it may never be the cause and yet the possibility often requires consideration. When flexion injury of a spine is soon followed by variations in density within a vertebral body, some wedging and later repair the cause of the condition will probably be found among such diseases as osteomyelitis, tumor, hemangiomatous vertebra, xanthoma or postmenopausal osteoporosis. If no causitive disease could be identified, the possibility of contusion

of the vertebra with subsequent aseptic necrosis might have to be considered.

Strain. The roentgen film does not visualize strain directly but it may demonstrate a protective posture which, in the absence of a visible lesion, suggests or even indicates strain. A persistent deviation of the spine without structural cause is usually a protective posture. This is particularly true for lateral and rotary deviations in the cervical spine and, in the lumbar spine, for decreased lordosis and lateral deviation. In the lumbar area, decrease of lordosis when standing as compared to the lordosis when lying in an habitual posture is definitely a protective reaction indicating that lumbosacral strain is present.

The roentgenogram also demonstrates the presence of structural variations which predispose to strain. Deviation of vertebrae as in scoliosis and weakness of joint tissues as in arthritis reduce the reserve of strength available to meet extraneous impacts and hence predispose to strain which may occur with apparently trivial injury. The lumbosacral area is a prolific source of mechanical weaknesses which predispose to lumbosacral strain.

Industry may make more use of the demonstration of these mechanical weaknesses than it has done in the past. The affected employee can be protected against strain. He should not be required to make some effort involving the affected area which is far beyond the effort to which he has been accustomed in the previous few days. After a long lay-off he should not return suddenly to full labor but should make increasing effort covering several days.

Anomalies which predispose to lumbosacral strain include transitional vertebrae, spondylolysis, posterior prominence of the fifth lumbar vertebra and several other variations. They all have in common one or both of two elements of mechanical weakness, unstable facets or unstable lumbosacral angle.

The stable lumbosacral facets are those which are well formed and face each other from side to side (the internal-external type). Instability arises when the facets are large, abnormally small, inclined laterally, asymmetrical or fail to face each other from side to side (the oblique and anteroposterior types). Marked asymmetry of the facets regularly results in strains beginning in the third decade of life.

The plane of the facets at the lumbosacral joint is easily judged in the anteroposterior view. If the lumbar facet completely overlaps the width of the sacral facet, the joint is the anteroposterior type; if the area of overlap of the facets is less than one-quarter of the total width of the facet shadows, the joint is the internal-external type. Various degrees of obliquity are indicated by degrees of overlapping intermediate between these two extremes. Fifty per cent overlapping corresponds to about 40 degrees of obliquity of the joint.

The stable lumbosacral angle is one in which the inclination of the superior surface of the sacrum to the horizontal in the habitual posture of the patient is not over 42 degrees; also, the center of gravity of the trunk as represented by a vertical line through the center of the body of the third lumbar vertebra passes not more than ½ inch in front of the sacrum. Instability arises when the inclination of the sacral surface to the horizontal is more than 42 degrees or the center of gravity of the trunk is more than ½ inch in front of the sacrum. Severe instability is present when the lumbosacral angle is as much as 52 degrees or the line of weight thrust is as much as 1½ inches in front of the sacrum.

These relationships are easily judged in a true lateral view of the lumbosacral area with the patient in his habitual posture. Unless the examination is carelessly done the bottom of the film represents the horizontal from which the inclination of the sacral surface can be measured and a line perpendicular to the bottom of the film drawn through the center of the shadow of the body of the third lumbar vertebra represents the line of weight thrust and its

relation to the anterior superior angle of the sacrum.

POST-TRAUMATIC CONDITIONS

Progressive Wedging of a Vertebral Body. Wedging after injury is practically never progressive in a vertebra which was previously healthy. If it does occur, it is slight. Progressive post-traumatic wedging should suggest disease. The condition usually present is postmenopausal osteoporosis with spontaneous collapse of the vertebrae. In this condition the vertebrae are undercalcified and wedged anteriorly with concavity of the superior and inferior surfaces and corresponding tendency of the intervertebral disc to be of spherical shape. Several vertebrae are wedged or soon become so.

Radiation of the neck stops the progress of wedging and relieves the symptoms of dull ache, weakness and fatigue in the back in this condition although some of the sharp pains on motion (due to accompanying osteoarthritis) may persist. This has been the result in each of ninety patients treated by the author. The right, left and posterior aspects of the neck in the parathyroid area are exposed to 150 to 200 r successively at intervals of three or four days. The series of three treatments is repeated at three-week intervals if symptoms are still prominent. Three or four series should suffice for relief of the patient.

Static Strain Due to Deformity. Just as developmental deformities causing mechanical weakness or instability may predispose to strain, so also may deformities resulting from dislocation or compression fracture. Kyphos establishes a weak structure which may result in strain. The predisposition to strain may be present not only at the kyphos but also at the lumbosacral area the posture of which is altered to compensate for kyphos in the low dorsal or lumbar area. In fact, the lumbosacral strain is apt to be the more troublesome to the patient and this area should be examined for instability in the manner that has been described.

Chronic Strain. When strain has occurred at an area (usually the lumbosacral area or a kyphos) where unstable structure predisposed to strain the patient may have difficulty recovering from the injury. Persistence or frequent recurrence of strain may then establish a chronic strain. The strain itself is, of course, not visible in the roentgen film but the predisposing unstable structure is demonstrable and should be studied and judged as has been described.

Where chronic strain persists for a sufficient length of time degenerative changes are apt to occur and become recognizeable as post-traumatic arthritis.

Post-traumatic Arthritis. Degenerative arthritis is indicated in the spine by lipping or spur formation at the vertebral margins with or without some thinning of cartilage at the facets or intervertebral disks. When the arthritis is evident only at one joint or area it is reasonable to conclude that the arthritis is post-traumatic. (Fig. 3.) When such a joint is subject to prolonged vibratory forces, as in riding on a train or truck, spasm about the joint may become very extensive and a very stiff painful back may result. That is the so-called "railroad spine."

ROENTGEN DEMONSTRATION OF VERTEBRAL ABNORMALITIES

The examination for the roentgen features which have been described should be based upon true anteroposterior and lateral views of the various regions of the spine. If the condition is not clearly determined by this examination, oblique and stereoscopic views may be added. For the first cervical vertebra a view through the open mouth is usually essential and for the lumbosacral joint a view which is anteroposterior oblique from below upward is helpful.

Routine views should ordinarily be taken in the supine positions but the erect position is often better for demonstration of protective postures, especially in the lum-

bosacral area. Estimation of the lumbosacral angle is best made in the supine position for the reason that, on standing, the pelvis normally tilts forward, increasing the lumbosacral angle, but when lumbosacral strain is present the pelvis tilts backward in a protective posture. Thus, the unstable lumbosacral angle which has led to strain may appear more stable when examined in the erect position. Obviously, examination in both positions can be used to determine that this protective reaction occurs and that lumbosacral strain is, therefore, actually present. This may be particularly useful when malingering is suspected.

Solidity of ankylosis or surgical fusion may be tested by examination anteroposteriorly or laterally in bent positions. Bending to the limit of motion in each of two opposite directions should reveal motion at the joint in question if ankylosis is not solid.

Laminography may be used for the demonstration of conditions at a particular plane within the vertebrae but this type of examination merely presents in a different manner the lesions or conditions which an able interpreter should see on the ordinary type films.

Injection of opaque material (or of air) into the neural canal is used for the demonstration of posterior protrusion of an intervertebral disk as has been discussed.

BACK INJURIES IN INDUSTRY

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FROM the records of the Industrial Accident Board of Massachusetts for 1944, there were 8,547 reported and contested back injuries. We believe these represent a fair cross-section of the United States as a whole and emphasize the importance of back injuries in industry, both in regard to lost time and lost wages, as well as the loss of production incident to such injuries. One must realize further that these statistics represent only a small proportion of back injuries, since only contested cases appear before the Industrial Accident Board. These figures emphasize the dire need of better diagnosis and treatment in relation to back injuries on the part of the medical profession as a whole.

It is evident that as orthopedic specialists we have failed to solve the enigma of the "industrial back." This may be due in part to the fact that so much consideration has been given to the theoretical side of back injuries and so little attention has been directed to the practical side. All the facts are present; it is our interpretation which is faulty and at times illogical. The orthopedist should make his diagnosis on the basis of positive findings only and not by a process of elimination or from theoretical considerations. In view of these facts we are in no position to criticize the average general practitioner of medicine for his treatment of all back injuries with adhesive strapping. We ourselves have failed to solve the problem of diagnosis and treatment of back injuries and therefore have been unable to give the general practitioner the help which he so justly and urgently needs.

ANATOMICAL CONSIDERATIONS

Under this heading one must consider the general build and musculature of the individual as a whole. There are many different anatomic types but, in general, we may say they are divided into the short, stocky, heavily-muscled type and the long, thin, small-boned, lightly-muscled individual. It is obvious that the former has a distinct mechanical advantage, of the lever and fulcrum variety, in doing heavy laborious work, and, as a result, is less prone to develop back injuries. These facts are of particular importance when one realizes that the muscles are the most important structures and the primary defense against bone, joint and ligamentous injuries.

Developmental anomalies are often considered to predispose to back injury. Among these are incomplete fusion of the sacrum, asymmetrical facets in the low lumbar spine of the inferior type, mechanically, increased lumbosacral angle with forward tilting of the pelvis, pre-spondylolithesis and other cingenital conditions resulting in the so-called unstable back. While we believe these conditions may predispose to back injury in certain individuals, there is no question that many individuals showing such types of so-called structurally weak backs, have no symptoms whatsoever under the most severe and heavy working conditions. One must, therefore, not be too positive in one's statement in regard to this group of cases.

PRE-OCCUPATIONAL EXAMINATIONS

From an industrial point of view all patients who are to be employed on specific types of industrial work warrant careful physical examination, both as to their general condition and as to their ability to perform heavy manual labor. Pre-occupational examinations by adequately trained medical men would do a great deal to alleviate most of the present troubles in relation to back injuries and disease. All individuals seeking employment in laborious work should be free from general disease, particularly diseases of the heart,

lungs and vascular system. A careful check-up should be made for systemic diseases, such as diabetes, nephritis, gastric ulcer and anemias. In simple language, pre-occupational examinations are definitely indicated, both for the protection of the employee as well as the employer. We do not believe that discrimination should be made against individuals because of the underlying disease, but we do believe they should be placed in jobs which they are physically able to do and adapted to their physical abilities for employment.

HISTORY AND PHYSICAL EXAMINATION

History. The history is of paramount importance in back injuries. This should include a careful consideration of the past history of the individual in relation to injuries, illnesses, diseases or operations, as these may have some important bearing on the present illness.

In respect to the present illness, one must carefully consider all the details in relation to the accident. One should endeavor to give an exact description so that one may visualize the actual mechanics involved: the position of the patient, the direction of the weight lifted as well as the amount, the extent of the muscular effort involved, the type of pain, including its character, distribution and precise location, and whether or not radiation of the pain occurred at the time of the injury or developed later. It is important to note whether the patient could continue working, or whether the patient worked some time and then had to stop on account of pain. One must then consider how the patient obtained relief from pain, whether by sitting, standing or lying down. The exact type of treatment given at the time of the accident and subsequent to the accident should be carefully listed. Proper evaluation should be given to the first medical examination. Previous attacks of back pain of any character should be noted.

Pain localized in the back which increases as the day goes on in direct ratio to the time the patient is on his feet and the amount of work which he performed is apt to be mechanical in origin. A pain which is severe when the patient arises in the morning and lessens as the activity of the day goes on is apt to be systemic in origin. Localized pain, non-radiating in character, with the history of a severe muscular effort in lifting, is almost always a simple muscle strain. Radiation pain down the leg or legs should be carefully localized by the examining physician and an accurate determination of its distribution should be made by plotting the sensory distribution. Such sciatic pain can usually be attributed to sacral 1 or 2, or sacral 1, lumbar 5 or lumbar 4, 5 sacral 1.

Physical Examination. First and of the utmost importance all patients presenting themselves for examination of the back or complaints referable to the back should be completely undressed, including shoes and stockings. The general posture of the individual should first be noted. This should include proper evaluation of the spinal curves, whether the head and shoulders are forward, whether the dorsal curve is increased or lumbar lordosis increased, or pelvis tilted forward, also whether the abdomen is relaxed. What is the state of the general musculature of the individual as a whole? Are the lower extremities symmetrical and straight? Do bow legs, knock knees, flat feet or any degree of pronation of the feet exist? Such an evaluation should be included in the first statement of the individual as a whole.

Along with this there should be a careful general physical examination to determine whether or not there may be a focus of infection in the nose and throat, the presence or absence of abscessed teeth the presence of cavities, gingivitis, pyorrhea, inflamed or chronically diseased tonsils, blood and pulse pressure, heart rate—all these should be noted. One should also check the lungs for any gross pathologic condition and examine the abdomen for any abnormal masses, spasm or tenderness. A rectal examination should also be done to

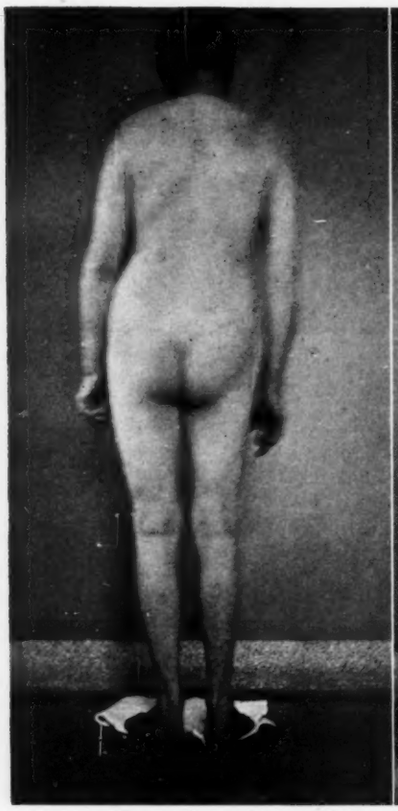

FIG. 1. Typical example of list; trunk shifted on plevis. Patient flexed forward at waist and right knee flexed.

FIG. 2. Forward bending; patient goes toward affected side, does not reverse lumbar spine and flexes right knee at the limit of forward flexion.

determine whether or not the prostate and rectum are normal.

After such a preliminary examination to determine the general condition of the individual from a physical point of view, our attention is then directed to the detailed examination of the back.

EXAMINATION OF THE BACK

Standing Position. The first position described is the standing position. In this, one notes whether or not there is a scoliosis present, and if so, whether this is of the functional or structural type. The functional type is usually due to a postural condition, often a short leg, and is of long-standing, usually developmental in origin. The structural type may be of any degree but if the curvature is of a severe type it is always accompanied by gross deformity of the ribs and a double structural curve. The type most often seen in back injuries is the so-called sciatic scoliosis which is accompanied by a very definite list. (Figs. 1 and 2.) This may be classified as protective in nature and caused by acute muscle spasm. It is well for the examiner to sit behind the patient on a chair or stool and carefully note the presence or absence of such a list: asymmetry of the hips, inequality in the height of the shoulders or other abnormality in relation to the spinal curves. A list of the trunk to the right or left with a tendency to flex the knee on the affected side in which radiation pain exists down the leg, indicates a deep seated lesion classified as low back disorders which include lumbosacral, sacro-iliac or intervertebral disc injuries. The patient is first asked to flex the body forward, relaxing the arms and keeping the knees perfectly straight or extended as much as possible. Normally, a

reversal of the lumbar spine occurs from a concave to a convex curve and indicates normal muscular action and normal segmentation of the vertebrae involved. If such forward bending, as is described above, is possible and complete reversal of the lumbar spine occurs, the presence of reflex muscular spasm can be definitely eliminated, whether this be from arthritis, nerve root compression, or some other type of deep seated injury. Following a reversal of the lumbar curve, forward tilting of the pelvis occurs on the trunk. This is accomplished by the iliopsoas muscles plus gravity. If deep seated injury or pathologic condition prevents this motion, i.e., normal reversal of the lumbar curve, the hamstrings do not relax, since they are the opposing group to the iliopsoas. In such a case the only manner by which the patient may fully flex the back or tilt the pelvis is by relaxation of the hamstring muscles by flexing the knees. To recapitulate, any patient who is able to stand without a list or without asymmetry, who is able to reverse the lumbar curve, tilt the pelvis with the knees straight touching the floor with his hands, come back to the erect position without discomfort or muscle spasm, may be eliminated from the possibility of any deep seated back injury. Next, lateral motions are performed to determine whether the curves of the spine are symmetrical and whether the motions in these directions are restricted by muscle spasm. Such limitation, if present, is carefully noted and accurately described as to degree and as to the point where pain is first noted. Hyperextension of the spine is then tested; the amount of motion present is determined and the point and location of pain carefully noted, if this exists, on extremes of motion. Rotation of the spine is also carefully checked and the presence or absence of limitation and pain recorded.

Lying or Recumbent Position. The patient is placed in recumbency on a well padded examining table and allowed to relax in a comfortable position before the examination proceeds further. Knee jerks and ankle jerks are tested. The lower extremities are then examined. The muscle tone of the legs is determined by palpation of the muscles and the presence or absence of deep muscle tenderness is noted. Any areas of disturbed sensation are also carefully noted as well as circulation in the extremities and motor function. The presence or absence of muscle atrophy is recorded and the calves and thighs are measured at corresponding points. Such measurements, to be accurate, must be taken from a fixed point. One ordinarily measures from the top of the patella to a point 6 inches up the thigh where a mark is made and the corresponding measurements recorded. On the calf, one ordinarily measures from the tibial tubercle to the maximum circumference of the calf. In any condition in which severe pain exists and there is nerve root pressure, atrophy of the quadriceps group quickly occurs from disuse and reflex irritation. Straight leg raising is then determined and is an extremely valuable test. The patient is asked to lift the leg with the knee fully extended. Both active and passive straight leg raising is usually done. Considering the recumbent position zero degrees, straight leg raising to 70 or 80 degrees or just short of a right angle is normally present, although a certain degree of individual variation exists. The value of this test lies in the fact that there is compensatory relationship in motion between the lumbar spine and the hip joint. Briefly stated, it is impossible for a person to raise the leg with the knee fully extended unless the lumbar spine is flat and free from muscle spasm. Conversely it is true that if a patient has a lumbar spine in spasm with limitation of motion, he is unable to lift the leg straight from the table with the knee extended without limitation of motion.

The patient is then examined face down. The tips of all the spinous processes are palpated by direct pressure. Exact points of tenderness are noted, particularly the point of maximum tenderness. If a lumbosacral strain exists, the pain is referred to the lumbosacral angle; if a sacro-iliac strain,

the pain is referred to the sacro-iliac joint and the superior and inferior sacro-iliac ligaments may be tender. In cases of simple muscle strain the erector spinae insertion or the muscle bellies themselves may be acutely tender. By feeling lateral to the erector spinae group, the quadratus lumborum muscle may be palpated by considerable pressure of the examining finger. The posterior iliac crests and the posterior spine of the ilium may be palpated, also the sciatic notch. The lumbar fascia and gluteal bursa should be carefully checked for the presence or absence of point tenderness. The sciatic notch and nerve and deep muscle tenderness are also recorded. Hyperextension of both hips is then attempted and the presence or absence of tenderness or muscle spasm noted. It is also possible in this position with the knees flexed and extended both to determine rotation of the hips, the presence or absence of muscle spasm and also abduction and adduction of the hips. This position is also favorable for determining ankle jerks, since it is easier for the patient to relax.

Sitting Position. A sitting test is now carried out. With the patient lying prone on the table, the examiner's arm is thrown across or above the knees, and without flexion the patient is asked to sit upright on the table. The normal individual should be able to go beyond a right angle without any discomfort. In deep seated conditions of the back and spine there is definite limitation of forward bending with superimposed body weight, and one finds that in a recumbent position the patient cannot come to within several degrees of a right angle and complains of pain and discomfort in the low back. This, of course, is due to the presence of spasm in the hamstrings, which prevents flexion of the pelvis on the trunk. (Many cases of the so-called malingering type may be detected by this test. These individuals often refuse to bend forward in the standing position more than a few degrees, but in this particular test in the recumbent position they will come to an upright position well forward of a right angle while sitting with the knees extended, which definitely marks them as malingerers.)

The mechanics of the feet should be carefully evaluated as they may be contributory factors in many persistent backaches. The predominant symptoms in pronated feet are fatigue, tiredness and discomfort in the back, increased in direct relation to the amount the patient is on his feet. Such cases may often be further complicated by peroneal spasm, pain and discomfort over the peroneal muscles. On examination, there is a good deal of tenderness in the pronated foot, both over the longitudinal and transverse arches, and at times short or tight heel cords may also be a factor. The presence or absence of bunions, callouses, circulatory disturbances, etc., should all be noted and properly evaluated, as they may be factors in low back pain.

We believe that the simplest way to consider the whole problem of the back is to evaluate the individual's general health, his past history and present illness, and then consider the back injury from a diagnostic point of view. Once the diagnosis has been established, treatment becomes relatively simple.

SIMPLE BACK STRAIN

The simplest type of back injury, we believe, is back strain or sprain. This condition usually occurs in an individual attempting to lift too great a weight, often under mechanical disadvantage or faulty body mechanics, or the lifting of moderate weights over a period of time under similar conditions. In such instances, the patient usually has great difficulty in straightening up or coming to the erect position. The pain is usually in the low back opposite the lumbosacral junction, or what we term the small of the back, or somewhere in the lumbar region. The pain, as a rule, is dull and aching in character and non-radiating in type. On physical examination (patient stripped) there is localized tenderness over the injured area, often at the erector spinae insertion into the sacrum. The tenderness

may extend to the lumbosacral junction. The lumbar muscles are obviously in spasm and any attempt at forward bending, hyperextension, lateral bending or rotation is checked by acute muscle spasm; if motions are forced, the patient complains of pain in the low back. As a general rule, symptoms usually develop several hours after the individual's muscular effort and are due to muscle spasm. Frequently, they do not appear until the following day when the patient attempts to get out of bed. These patients are suffering from acute muscle strain and the treatment is relatively simple. Such cases respond to local heat, particularly in the form of moist, wet heat employed by hot Turkish or bath towels or a hot pad. In our opinion, the back should not be strapped. Adhesive strapping is inefficient and does not actually immobilize the back in any sense. If the patient is so incapacitated that he is unable to pursue his occupation, rest in bed with some counterirritant as heat is without question the proper treatment. Massage is often of inestimable value and is particularly beneficial when most of the muscle spasm has disappeared. In some instances, simply hitting the low back muscles, i.e., lumbar muscles, with the flat of the hand or by ironing the muscles with the application of towels to protect the skin, may afford relief. At times such relief is spectacular. In cases of simple back strain, disability should not exceed five to ten days. This is the simplest form of back injury and presents no particular problem.

DEEP SEATED BACK STRAIN

Next one must consider deep seated low back strain, and this we believe to be the most common of all back injuries. This is a deep seated and complicated type of injury and not to be confused with simple back strain. Often there is an underlying background of either a posturally weak back, the presence of hypertrophic arthritis, or degenerative age changes, and in addition there is frequently history of repeated back injuries. Such cases usually give a history of dull aching pain at the lumbosacral junction, which, characteristically, does not radiate down the leg but may radiate down the thigh as far as the greater trochanter or slightly below. The maximum pain and discomfort is over the lumbosacral junction with complaint of dull aching pain in this region, usually increased by occupation, particularly if it entails a good deal of standing, stooping or lying. Such cases deserve a careful examination of the feet, consideration of their general posture, and usually represent a combination of mechanical and muscular difficulties. If the feet are pronated, this condition should be connected by proper support of the arch at the inner border of the foot. Bow leg or knock knee should be adequately treated. Increased lordosis is usually an indication of faulty body mechanics and most often it is a combination of this and relaxed musculature. Such cases require supportive treatment both in relation to the feet, lower extremities, lumbosacral junction, and in addition the general musculature of the individual should be toned up. We believe that the increased lumbosacral angle can best be treated in the initial phases by proper supportive treatment with a rigid type of back support. Such a rigid brace, properly fitted, will give definite relief of symptoms referable to the lumbosacral region. We do not believe that this should be permanent in any sense and as soon as the patient has obtained relief from symptoms over a sufficient period of time, active exercises should be instituted to improve the musculature of the back and abdomen. This, together with proper postural training, should enable the individual to eliminate the use of the brace. Such cases usually improve fairly rapidly under this regimen. There is often a decided tendency by both doctor and patient to prolong the use of braces and supports unnecessarily.

Sacro-iliac Strain. It is the belief of both authors that this condition, as an entity, rarely exists other than incidental to the relaxation that occurs in preg-

nancy or actual disease of the sacro-iliac articulation.

The authors have further noted that in true cases of traumatic evulsion of the sacro-iliac joint in which the entire half of the pelvis was displaced upward about ¾ inch, the chief complaints were referable to the anterior aspect of the thigh along the distribution of the femoral nerve rather than the sciatic nerve. However, we believe that reflex irritation of the sciatic nerve may occasionally be encountered although this is not characteristic. Where actual disease of the sacro-iliac joint exists, fusion or immobilization is definitely indicated.

We must now consider a much larger group of cases in which the complaints and the patholic conditions are much more deeply seated and more difficult of diagnosis. This is a group of cases accompanied by radiation pain, many of which show sciatic scoliosis. These cases are very difficult to evaluate and diagnose. Many show a list, limited forward and lateral bending, rotation, limitation of straight leg raising, positive sitting test and often diminished ankle jerks. In many instances *x*-rays may be negative. There is no doubt that a certain small proportion of these cases may represent rupture of the intervertebral disc. Specificially, such cases show radiation pain down the outer side of the thigh, lower leg and outer side of the foot over the sensory distribution of first and second sacral nerves. They also show tenderness over the sciatic nerve and deep muscle tenderness; oftentimes they have spasm and atrophy of the affected muscles of the extremities and occasionally muscle weakness to a noticeable degree. The ankle jerk on the affected side is often diminished or lost and not infrequently there is disturbance of the sphincters, either bladder or rectum. Pain is a very characteristic symptom and often may be severe in quality, so that the patient is unable to sleep without sedation. It is our belief that this group of cases, even though a rupture of the intervertebral disc may be suspected, all types of conservative treatment for relief of the symptoms should be thoroughly tried before the patient is hospitalized for intervertebral disc surgery or investigation. In the first place, such cases often respond to simple back treatment. Such cases should be put on fracture boards with no privileges, to remain absolutely quiet in bed for a period of ten days to two weeks, and should have local heat, massage and supportive treatment. In many instances, the symptoms will clear up without further treatment. If muscle spasms still persists at the end of ten days, we believe that traction of the affected extremity should also be tried. Oftentimes, relief may be obtained by the injection of novocaine and saline into the so-called local or trigger points of tenderness. If the patient does not respond to such treatment, manipulation of the back is definitely indicated. This, of course, requires hospitalization and the general condition of the individual as an operative risk should first be carefully evaluated.

TECHNIC OF MANIPULATION

The gastrointestinal tract is completely cleansed with enemas or mild cathartics. The affected leg is shaved. This is all done on the night prior to manipulation. Under general anesthesia, the patient lies relaxed back down on the table. An assistant then supports the opposite side of the pelvis and the manipulator, with the patient's leg fully extended at the knee, stretches the hamstrings. In performing this act, the operator carries the leg well beyond a right angle in his first stretching, then brings it back to the horizontal position. Each time he stretches he goes a bit further in his manipulation. In some instances, one stretches the leg almost to the point of putting the foot on the forehead. A complication which has occurred a few times in over 300 cases is that the head of the femur slips over the posterior lip of the acetabulum (which is startling to say the least) but it replaces itself very rapidly when the leg is brought straight again. When the

hamstrings are considered thoroughly stretched, the patient is turned over on his face, with a pillow placed under the chest to improve the breathing. The operator then places his right arm under the patient's thighs and lifts the legs and pelvis to hyperextend the spine. In a true low back strain, even with the patient anesthetized, one is not able to define a good lumbar curve of the spine until the pelvis is given a torsional twist. Here it may be stated that in a very small percentage of cases a definite click has been heard and a well defined lumbar concave curve results. The patient is then rolled on his back and 15 pounds of extension applied with adhesive moleskin. This should be done before the patient has come out of ether. The patient is then left with this extension on for a period of ten days to two weeks during which time he is not allowed to raise his head from the pillow. On the tenth to the fourteenth day the patient is relieved of the extension, allowed to roll around in bed for a day or two, and then get up on crutches for a week, using no support in the form of a brace or jacket on the back.

The post-manipulative convalescent period is sometimes attended with discomfort over the tuberosity of the ischium, which we suppose is due to the pull on the attachment of the hamstrings. The questionnaires returned from about 300 cases showed that about 75 per cent had had entire relief of discomfort in the back without any recurrence. We believe that the other 25 per cent fall into the class which should be investigated for possible intervertebral disc disorders.

There is a real possibility that in doing these manipulations we reduce a certain percentage of cases which have protrusion of a disc. This being true, why not manipulate and reduce any given case with a proven defect by myelography? This would eliminate at least temporarily the necessity for open operation.*

RUPTURED INTERVERTEBRAL DISC

We are of the opinion that on the whole the results from operations performed for ruptured intervertebral disc are appallingly bad. At the present time, the enthusiasm for this operation has gotten beyond the bounds of common sense and logic. Patients are often operated upon without adequate study and many times before any other type of treatment has been instituted. It is our opinion that many discs get well without operation as they did prior to the institution of operation for ruptured disc. Furthermore, operation should be performed only after all available methods of treatment have failed to give relief. When such a procedure must be done, we believe it should be done with the close cooperation of the neurosurgeon and the orthopedic surgeon.

One must now consider hospitalization of the patient who has failed to respond to all methods of conservative treatment for diagnosis of ruptured intervertebral disc. At this point, consultation between orthopedist and radiologist is most essential. A lumbar puncture should be done and a careful hydrodynamics of the spinal fluid should be carried out. This should include initial pressure, pressure with respiration, pulse, jugular compression (both single and bilateral), pressure after removal of 5 and 10 cc., and a chemical analysis of the spinal fluid, to include total protein, Hinton, and in certain cases, colloidal gold test. *X*-ray visualization of the spinal canal is also definitely indicated. At the present time, lipiodol or air visualization is seldom employed. (Figs. 3 and 4.) Pantopaque seems to be the opaque dye of choice, at least in the New England States. A positive test with a definition defect is very helpful in diagnosis and localization of the lesion. One must realize, however, that even in the

* A complication which has been noted in six to eight cases out of the series is an ileus appearing twenty-four to forty-eight hours after the manipulation. This has occurred in cases in which there has been a history of chronic constipation in which there is not a pre-manipulative intestinal elimination. In one patient in whom acute dilatation of the stomach was a complication, it was necessary to introduce a Wangensteen tube.

Fig. 3. Characteristic obliteration of nerve root on left; proved disc by operation.

Fig. 4. Nerve root on right L3 and L4, showing an extremely slight defect. This patient got well with conservative treatment without operation.

presence of a negative chemical test, hydrodynamics or *x*-ray visualization, there may be a rupture of the intervertebral disc, in which connection it is very essential to evaluate the complaints of the patient in regard to low back pain. If the individual is of stable character and has severe pain consistent in type, in spite of negative tests, exploration in our opinion is definitely indicated and a high percentage of positive ruptures will be found in such cases. It is our belief that fusion can be determined only at the time of operation by actual demonstration of the laxity or solidity of the low lumbar spine and lumbosacral junction. If the junction is practically immobile as demonstrated by grasping the fifth lumbar with a clamp and attempting to induce mobility under anesthesia, fusion is definitely not indicated. On the other hand, if abnormal mobility exists, fusion is definitely indicated whether a disc is present or not. This is particularly true in patients with an unstable back as seen by *x*-ray, an increase in the lumbosacral angle or a congenital variation of the lumbosacral junction and a history of repeated back pain.

The treatment of back injuries is often complicated by injuries of bone. These include injury to the spinous processes, laminae, articular facets or vertebral bodies.

In relation to fracture of the spinous processes, we believe that these are often very much overtreated and that ordinarily not more than three to six weeks of disability should be anticipated, with the usual supportive treatment, such as a Thomas collar in the cervical region.

Fractures of the laminae, provided there is no displacement or interference with the central nervous system, are of relatively minor importance and such cases should be able to resume work within four to eight weeks.

Compression fractures of the vertebrae without neurological symptoms, or even with neurological symptoms, we believe should be treated by hyperextension, and, in our opinion, this is best done under an anesthetic when reduction may be im-

mediately accomplished, as is done with fractures of the long bones. This eliminates the pain and discomfort of gradual hyperextension and insures an adequate reduction. Such cases are put in hyperextension in a plaster cast and following this may be allowed to roll about in bed freely. No weight-bearing is allowed, however, in these cases for at least eight or nine weeks. At the end of this time, the plaster cast is removed and a rigid type of long back brace applied. This should be worn for an additional three to four months. At the end of this time, the brace is eliminated after the patient has developed his musculature to a sufficient degree. He may then return to work. Such fractures usually mean about six to eight months of disability, on occasion this may extend as long as one year.

Fractures of the transverse processes, in our opinion, are usually overtreated. We believe that these should not be immobilized in plaster but the patient put to rest in bed until muscle spasm disappears. Following this, he is gotten up and about and as soon as he feels physically able he may return to his work. In our opinion, it is of no significance whether or not these processes unite by *x*-ray, since most of the patients have no symptoms.

ARTHRITIS

The commonest type of arthritis encountered is the so-called hypertrophic arthritis which is seen in a large majority of individuals after the age of forty. We wish to call attention to the fact that this type of arthritis involving only the vertebral bodies, is degenerative in nature and not accompanied by symptoms. It is only when the articular facets between the vertebrae become involved in the process that symptoms occur. One should be careful in using the expression, arthritis, as applied to degenerative changes since many people have a horror of the crippling deformities incident to a degenerative arthritis, particularly of the deforming type. There is no doubt that many of these individuals have referred pain and in many instances the intervertebral foramina may be distinctly narrowed. We believe that such individuals are prone to inflammatory changes, irritation of nerve root and symptoms of referred pain. In such cases, there is usually no history of a definite injury; they are doing their regular work when they suddenly have acute pain in the back and often radiation pain along the course of the sciatic nerve. A careful examination often reveals a focus of infection, particularly in the nose, throat or teeth. Correction of these underlying conditions will usually clear up the disability which is one of neuritis.

The four specific types of arthritis for which the etiology is known are tuberculosis, syphilis, gonorrhea and gout. In each case the condition is non-industrial and there is only the possibility of aggravation to be considered in relation to their occupation. In such instances, the aggravation factor can only exist for a reasonable length of time, which will depend somewhat upon their age and general condition. We believe that the ultimate course of disease is not influenced by trauma but symptoms of the injury may be prolonged.

EPIPHYSITIS

Epiphysitis of the spine is a more serious condition than is generally recognized by the medical profession. The centers of ossification are extremely active in young individuals between the ages of twelve and eighteen, particularly in relation to the vertebrae. (Figs. 5 and 6.) Certain industrial occupations which require bending over a long period of time may predispose to the rounded back so often seen in later life. A seemingly trivial injury may cause damage to these epiphyses. These individuals show the so-called rounded back and should not be employed industrially for any work which requires lifting, stooping or bending. Oftentimes, this condition seems to be hereditary and we have seen numerous examples in which the condition has been present in both the father, mother and

FIG. 5. Typical posture of a sitting test in a young boy with acute epiphysitis following injury.

children, and in some instances even in the grandparents.

SPONDYLOLISTHESIS IN RELATION TO BACK INJURY

It is our belief that this is usually congenital in origin and we have never seen a case of traumatic spondylolithesis of the lumbosacral junction which could be definitely proven to be entirely traumatic in origin except where fracture also occurred. We also believe that this condition is much more prevalent than is ordinarily recognized. In our experience, most patients begin to show symptoms as a result of advanced age with increase in body weight and subsequent change in body mechanics. Slipping is usually of a gradual degree and is not the result of any one specific accident. Therefore, in relation to industry there is only the question of aggravation to be considered and such aggravation we believe should be limited to a period of three to four months at the most. We do not think that sacralization of the transverse processes or impingement of the spinous processes, except possibly in rare instances, are the cause of back symptoms.

OSTEOPOROSIS

Osteoporosis or bone atrophy may at times be a complicating factor in back injuries. It is often found in old age and occasionally in middle life. It is progressive in character, and, in our opinion, not aggravated by a specific trauma. It is usually associated with a glandular imbalance. Trauma may conceivably aggravate the underlying condition. It is difficult to state how long such an aggravation should reasonably exist and how much disability should reasonably be allowed. It is our belief that eight to twelve weeks is certainly a generous allowance, but this will vary with different individuals and different doctors.

INCONSISTENT SIGNS AND SYMPTOMS IN RELATION TO BACK INJURIES

It has been estimated that in from 10 to 20 per cent of all back injuries certain inconsistencies are found. A certain proportion of these fall into the group known as malingerers. Malingering may be defined as an attempt on the part of a patient wilfully to deceive the examining physician in relation to his signs and symptoms. Several methods of detecting such inconsistencies are noted:

1. In putting the patient through motions of the back in forward bending, we find many times that he refuses to flex forward at the hips, holds himself rigid, trembles all over and is sensitive no

matter where touched. This observation makes one suspicious. Our method has been to put this patient through the entire examination as previously described, leaving to the last the sitting test. The examiner then puts the patient through essentially the same mechanical motion without superimposed body weight, and in placing the arms across the knees, one finds the patient inadvertently going well beyond a right angle.

2. In observing the patient dressing and undressing, he will many times refuse to bend forward, and yet he will stoop over and pick up his trousers from the floor, pull them on over his feet and legs without the slightest difficulty.

3. Straight leg raising is another test. The patient here will refuse to raise the leg. The examiner carries the leg gently up and holds it to the full straight leg raising range, 70 to 90 degrees, and then asks the patient to hold it there. He does it without the slightest difficulty and is using exactly the same muscles and flattens out his lumbar spine in exactly the same manner as he would in normal straight leg raising.

Fig. 6. Forward bending markedly limited in a young boy with acute epiphysitis.

SUMMARY

1. This is a plea for more careful examinations and proper interpretation of symptoms in the case of industrial back injuries.

2. Closer cooperation between orthopedist, neurosurgeon and radiologist is urged.

3. Less emphasis should be placed upon congenital malformations as expressed in the *x*-ray. Their importance should be properly evaluated in any given case and not overemphasized to the patient.

4. The surgeon should rationalize the entire subject of ruptured intervertebral disc disorders, and attempt to classify symptoms, evaluate myelography and curb the hyperenthusiasm of operative procedures which is sweeping the country at the present time.

5. He should eliminate the use of adhesive plaster as a universal treatment for acute conditions of the back and minimize the number of braces and jackets applied indiscriminately in injuries to back, as they only tend to produce muscle atrophy and prolong convalescence in a fair percentage of alleged back injuries.

6. It is our opinion that if the proper evaluation is given to the patient's history, physical findings, *x*-ray and laboratory findings, each individual may be diagnosed and treated on a scientific basis. If such measures are taken, much of the bugaboo which now confronts us in relation to back injuries will be eliminated.

OPERATIVE INDICATIONS IN TRAUMA TO THE LOW BACK

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LOW back pain, post-traumatic and following disease, has always been and is one of the most common and confusing problems confronting the physician. A review of both conservative and operative methods that have enjoyed popularity at various times during the past forty years indicates almost total disunity of opinion of workers in this field.

It is our purpose in this brief paper to discuss the major indications for operative interference in certain conditions of the lower back. Even though time and work have enhanced our knowledge all is not serene, disagreement being only slightly less than in prior years. For the sake of clarity we will deal in principles of history and examination, rather than technic.

May we stress at the start that of all patients examined with traumatic back pain only an exceeding few should require operative interference, certainly less than 5 to 10 per cent. A sound knowledge and program of conservative therapy is the foundation of all treatment of the back. This involves not only thorough studies of anatomical and postural mechanics, but an understanding of the physiopathologic state of the related organism as a whole.

CASE HISTORY

The well organized history, as always, is the most important single item in studies of the back. A careful, unhurried history will often provide the diagnosis if properly interpreted. The usual complete medical history routine is desirable with certain specific additions. The following plan is suggested:

I. *Injury:*

(a) Nature of injury: direct violence, indirect compression, bending or lifting strain

(b) Extent and severity of injury

(c) Prior injuries

II. *Pain:*

(a) Site and radiation

(b) Severity and quality of pain

(c) Intermittent or continuous attacks

(d) Relation of cough or sneeze to local pain and pain radiation

(e) Relation of pain to normal posture and postural changes

III. *Posture:*

(a) Changes in posture noted by the patient

IV. *Activities:*

(a) Amount of limitation of normal activities such as daily work

(b) Type of bed mattress habitually used should always be known, as it may be directly related to the complaint

The systemic history may give much useful information. Through it the psychoneurotic personality shows itself, perhaps better than at any other time during the consultation. Of special importance in this phase of the history is a careful evaluation of genitourinary disease.

PHYSICAL EXAMINATION

Here as in the taking of the history, the whole is to be considered first and not the isolated complaint. Careful observation of the patient's general appearance and a basic physical examination are essential to a correct diagnosis. Listed below are additional specific observations to be made in examination of the low back:

I. *Posture (both static and dynamic):*

(a) *Ambulation:* Is the patient ambulatory? And if so, does he walk with a natural gait and without limp or does he hold himself in an abnormal posture while

walking? Does he favor one leg while walking?

(b) *Ordinary Motions:* It is worth while to observe the patient while undressing or making other movements not related to the physical examination. Observation of the removal of shoes or stockings will give an index of the true amount of back disability.

(c) *Static Posture:*

(1) Foot attitude and distribution of weight between the two lower extremities

(2) Alignment of the legs

(3) Lumbar posture—Is the lumbar lordosis average, increased or decreased?

(4) Cervical and dorsal posture—Is there an average dorsum rotundum?

(5) Lateral list—Is there a tilt originating in the low back area?

(6) Is the pelvis level or tilted?

(7) Lateral deformities of the spine; e.g., scoliosis

(d) *Maneuvers or Tests Related to the Posture:*

(1) Motions of the spine both standing and supine—Right and left lateral flexion. In doing this test, freedom of motion, reference of pain and any difference in the point of origin of motion in the low back are of extreme importance. Any increase in muscle tonicity should be noted.

(2) Flexion of the spine—The ability to complete this maneuver has wide variance but its relation to pain may be of importance in diagnosis. A deviation of the spine to the right or left in forward flexion will indicate unequal muscular contracture in the low back.

(3) Extension of the spine—Any reference of pain from the low back to either or both lower extremities may be of definite diagnostic aid in this test.

(4) Rotation of the spine—In chronic back pain most commonly seen rotation of the spine is not particularly painful. Should the cause, however, be in the facet region, this test will usually be positive with pain production.

(5) Straight leg raising—Limitation in this motion with the patient supine is an indication of both sciatic nerve irritation and contracture of hamstring and low back musculature. It forms an excellent clinical test of the progress of conservative treatment in low back conditions. Care, however, must be taken in interpreting this test, as a sense of tension restricted to the popliteal space is normal to most patients. Pain along the posterior aspect of the thigh extending into the buttock or low back indicates pathologic change.

(6) The hyperextension test—This may be done in many ways; perhaps the most effective is that described by Duncan and Hoen. The patient is placed supine on a rather high examination table with legs extended over the end just below the level of the hip in such a way as to extend effectively the lumbar spine. When positive, there will be a gradual rising tide of pain following the course of the involved sciatic nerve to thigh and calf. Flexion of the opposite leg acutely at the hip flexes the back and the pain is relieved. It is, of course, particularly useful in the diagnosis of herniated nucleus pulposus.

(7) Pelvic compression—This, to our minds, is the simplest test for true sacroiliac pain of the many that are available. With the patient supine, pressure is placed medially on both outer iliac crests simultaneously. When positive, the patient will localize this pain in the region of the sacroiliac joints.

(8) Local tenderness—The exact site of local tenderness either in the low back area, buttocks or lower extremities should be carefully observed and evaluated at each examination. It should be localized in reference to anatomic landmarks.

II. *Neurological Examination:*

The tests mentioned here apply principally to the lower extremity. It is wise, however, to include the trunk and upper extremities in this examination to exclude central neuropathologic changes.

(a) *Atrophy:* Atrophy of calves or thighs may be observed by mensuration of circumferences. Gluteal atrophy may be

noted by viewing the prone patient from the foot of the table.

(b) *Reflexes:* Deep response of the glutei, hamstrings, quadriceps and triceps surae should be tested. Abnormalities in the superficial reflexes should be noted as well.

(c) *Sensorium:* Localized abnormalities of skin sensation may be of diagnostic significance, or may aid in localization of spinal lesions. Kinesthetic and coordinational changes may be signficant.

(d) *Motor Power:* Evaluation of muscular power and tone is worth while for purposes of diagnosis and localization of the lesion.

(e) *Jugular Compression, (Naffziger test):* Increase of intraspinal pressures produced by jugular compression may excite pain along the radiation of a nerve affected by an intraspinal lesion. A negative response to this test does not, however, rule out pathologic changes within the spinal canal.

III. *Roentgenological Studies:*

Good *x*-rays go hand in hand with the careful examination. One is incomplete without the other. Suggested routine views are as follows:

(a) Anteroposterior and lateral views of the lumbar and lumbosacral areas.

(b) A 45 degree anteroposterior view of the lumbosacral joint. In this view the central radiations are directed as parallel as possible to the plane of the lumbosacral joint.

(c) If lesions of the small posterior articulations or the sacroiliac joints are suspected, oblique views of the areas involved should be made.

(d) One of the many technics for measuring leg lengths roentgenologically will occasionally be found useful. Other special roentgenological studies will be considered in those conditions in which they apply.

PATHOLOGY OF BACK TRAUMA

Spinal fractures are excluded from this study as they are a field unto themselves, each being treated on its own merits. Most pain arising from trauma is caused by changes in the supporting soft tissues. It will be well to consider these changes as they apply to low back pain.

In many instances the lesion is a simple strain or tear of the tendinous insertion of supporting musculature which seldom requires surgical intervention. In recent years our attention is directed more and more to the tissues supporting the intervertebral articulations and to the intervertebral disc.

It will be remembered that the intervertebral disc is comprised of the annulus fibrosus, a series of concentric dense layers of fibrocartilage surrounding the central semi-fluid nucleus pulposus. Support is provided not only by the annular ligament but by other interosseous ligaments and the posterior articular facets.

The lower lumbar articulations support much of the trunk mass and provide greater mobility than other spinal joints, thereby increasing their vulnerability. Ninety-five per cent of back lesions will be found in this area.

Bending or twisting injuries to the trunk will, perforce, place greatest strain near the center of motion, namely, the low back articulations. Lateral and rotary motions are adequately protected by the facets but other forces may produce injury to the annular ligament. This structure is weaker in its posterolateral margin than elsewhere; and since forces applied are usually in flexion, lesions are commonly found in the posterior half of the ligament. The extent of injury may vary from a mild strain to complete rupture with extrusion of the disc forcibly into the spinal canal. The simple ligamentous injury without nuclear protrusion is the usual result of the primary back trauma. It is amenable to a program of support and rest. All too frequently, however, the trauma will initiate a progressive degenerative lesion of the disc structures. The annulus becomes thin and may fibrillate. With or without a secondary injury the now fibrotic nucleus extrudes into the spinal canal exciting radicular pain through its pressure on nerve roots. It is, of

course, possible to have disc extrusion without nerve root involvement, but this is uncommon. Following extrusion, the involved joint generally becomes thin and in time hypertrophic changes will supervene. Nerve roots involved by disc pressure, if not relieved, may in time develop local fibrotic changes and loss of function. Prognosis for relief of pain in these chronic lesions is poor by any method of treatment.

Other structures than annular ligaments may indeed be involved by back injuries, but this structure is the most frequent victim in our experience.

The facet articulations with their surrounding soft parts are subject to strain and injury, and ligamentous tears in the region may lead to chronic back disability. Underlying congenital bony anomalies may enhance the possibility of ligamentous damage following injury and will require careful consideration in planning treatment.

Before considering specific lesions, it will be wise to establish a basis of treatment. The exact source and cause of pain in low back injury is in many instances not known, but it appears safe to say that practically all such pain is related to strain or injury of the soft parts. Physiologic repair of these tissues will require as it does in other parts of the body physiologic rest. Rest then is the basis upon which our efforts of treatment are founded. The type of rest desired will depend upon the condition present and its severity. In the acute low back strain there is no substitute for absolute bed rest. An older method of treatment which is still popular is manipulation under anesthesia followed by immobilization in a plaster of paris jacket or spica for a rather prolonged period. It seems to us that the period of rest thus provided accounts for the beneficial results. In the mild, chronic, recurring back pain in which periods of relief are obtainable, rest of the strained and inflamed ligaments may be actually obtained by effecting a proper postural habit through exercise. Occasionally the use of a back support may aid in achieving this end but it is needed permanently only in debilitated persons or those refusing operation. Where surgical interference is indicated, absolute rest is obtained through bony arthrodesis. We would re-emphasize the importance of a conservative outlook in the treatment of low back conditions. Surgery, we believe, should be reserved as a final answer, except in those instances that would indicate chronic disability without it.

HERNIATED NUCLEUS PULPOSUS

It was a brief fifteen years ago that Barr and Mixter first described this condition and its part in the production of pain. In that short period this diagnosis has become more frequent than almost any other as a serious cause of low back disability. There is no doubt that in this wave of popularity the diagnosis has often been misused, but with added experience and new methods, much greater accuracy is now possible. We are able, therefore, to describe the symptoms of the "typical" disc lesion. Before doing so, however, the reader must be warned that here as elsewhere there is always the atypical occasional case to challenge our diagnostic skill.

The complaint is one of sciatica; pain is distributed down the posterolateral aspect of the thigh into the lateral aspect of calf and foot, and back pain is present. Low back pain will usually have been initiated by bending or lifting strain. The pain improves and is then followed by leg pain. It is not at all infrequent, however, that back pain has not been present at all and sciatica has been the only complaint. Pain is usually intermittent but in nearly 25 per cent of patients it will have been more or less continuous. Leg pain is increased on coughing, sneezing or on straining at stool. The patient has noticed some change in his posture, one hip becoming more prominent. He is most uncomfortable on sitting for long periods; standing in one place is also tiresome. He is usually happiest while walking; and rest in bed, if carried out over a long period, will tend to give him some relief. The examination will

reveal that he tends to take most of his weight on the painless foot, and he stands with a list away from the side of the pain. The lumbar lordosis is flattened and there is increased muscular tonicity in the sacrospinalis groups. In seeking comfort, he will tend to flex the painful leg at hip and knee. Lateral bending to the side of the lesion will produce increased radiation of pain down that extremity. Extension of the spine will do likewise. Rotation of the spine is usually free and painless. Straight leg raising will be definitely limited and painful on the affected extremity, and there will usually be tenderness over the spinous process of either L4 or 5 or over the paravertebral musculature on the affected side. Where the pain has been of long standing there will be thigh, calf and buttock atrophy, and there will be loss of buttock tone to be tested by palpation of the glutei. The tendo-achilles reflex on the affected side is most often absent, but other reflexes may be diminished in its stead. The gluteal reflex is frequently found diminished or absent. In cases of any severity, there will be tenderness along the course of the sciatic nerve in the buttock and thigh. A localized point of tenderness is frequently found on deep palpation of the gluteus medius muscle just above the greater trochanter of the hip on the affected side. The lesion occurs in 95 per cent of patients either in the fourth or fifth lumbar interspaces. Therefore, deep percussion in this area will frequently produce sharp radiating pains along the course of the affected sciatic nerve. There is frequently weakness of big toe flexion and/or extension. Sensory examination will show hypesthesia or anesthesia along the dermatomes of L5 or S1, the latter being the most common. Jugular compression will usually produce pain along the sciatic radiation and the extension test described above is most frequently positive. It must be reiterated that the above findings represent the average and that variance in one or more is by no means uncommon. The spinal list, for example, may rarely be toward the side of the lesion rather than away or may actually alternate from one side to the other within the period of a single examination. This latter finding usually indicates a midline disc lesion.

There are certain special roentgenologic technics which will be of great help, not only in establishing the diagnosis but also in localizing the lesion and in determining the type of operation to be done. The routine low back *x*-rays may indicate the site of the lesion through a narrowing of the affected intervertebral space. This, however, is not usual in the young adult who has suffered for only a short period. When this occurs at the lumbosacral junction it may be misleading as this joint is frequently congenitally narrow. Anteroposterior films, showing lateral bending of the lumbosacral spine will in about 40 per cent show a failure of closure on one side of the disc space involved. We do not believe that this test is diagnostic, but it may be a definite aid in localization of the lesion. Probably the most important radiologic development has been the myelogram. At first this was done with air or oxygen but has been generally found inexact because of failure of sharp contrast. Lipiodol was then injected into the dural space and gave an excellent picture but was found to be rather difficult to remove *in toto* and dangerous if left in place, as in many instances it produced subarachnoid irritation. A new substance, pantopaque, has been developed in recent years as a contrast medium. (Fig. 1.) It is said to be non-irritating on the meninges. It is somewhat easier to remove after the myelography has been done by needle than was lipiodol and any that is left in place is slowly absorbed without producing pathologic changes. The technic is simple but requires some care, patience and expert roentgenologic interpretation. While the diagnoses thus obtained from positive roentgenograms are very definite, it must be borne in mind that a disc protrusion may exist without showing any change in the column of contrast medium. As shown by Spurling, the mere absence of an axillary node in the shadow may be diag-

nostic, and it is such minimal findings that will require careful interpretation. Above all, a pantopaque myelogram helps us to anticipate the finding of cord tumor, cyst or other intraspinal lesion instead of the expected disc.

While discussing special tests it is wise to mention spinal puncture and cerebrospinal fluid analysis. This is generally not considered as important in the average case as it was a few years back, the reason no doubt being that we now have a better understanding of the clinical findings indicative of disc. In any case in which myelogram is done, spinal fluid should be obtained and studied. In a doubtful case, even though myelogram is not planned, a spinal fluid study is certainly indicated. More often than not the spinal fluid in the true disc will be found to be normal, but slight to moderate elevations in spinal fluid protein content are not at all unusual. The value of the spinal fluid study is most important in ruling out other sources of complaint.

The decision as to the choice of treatment to be employed will depend upon a number of factors. To the general medical profession as a whole the diagnosis of herniated nucleus pulposus seems to predicate surgery as the only form of relief. Since the lesion may vary from a mild strain of the annular ligament to a complete eruption of the entire nucleus into the spinal canal, this above impression is by no means true. The majority of disc lesions can be successfully treated conservatively. Where long periods of complete relief have been experienced between mild typical attacks of pain, conservative treatment by rest, supervised exercise and possibly brace is usually successful. In such instances, however, when a period of absolute bed rest over a period of one to three weeks fails to give subjective relief or improvement in objective findings, operative interference is indicated. In patients with acute pain following closely on initial trauma, a period of bed rest will be the best indication as to the type of treatment to be

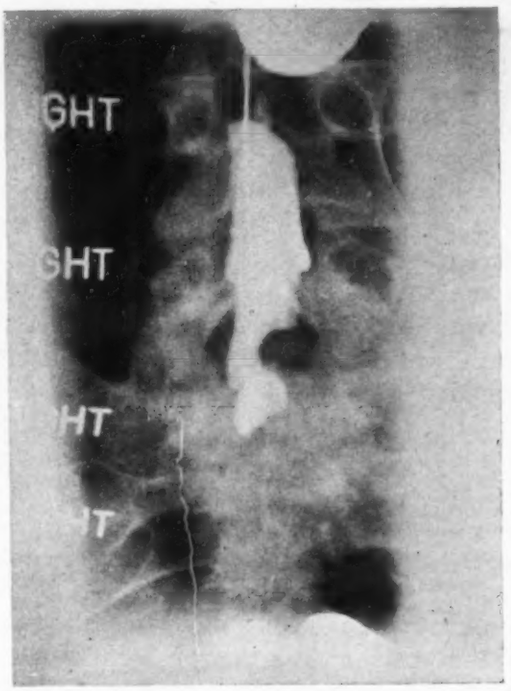

Fig. 1. Pantopaque myelogram; large defect is present at lumbosacral level, left.

followed. It is rare that operation is needed at this time, and properly applied conservative treatment allowing complete healing of the injured disc ligaments may do much to prevent recurrence of the difficulty in the future. If, however, clinical changes as outlined above persist in spite of carefully administered rest, operation will be the logical choice in order to prevent permanent nerve root injury.

There are certain patients seen with extreme symptoms from the onset which demand early operation without thought of conservative treatment. These patients are admitted to the hospital by ambulance because they are completely unable to walk. The pain is excruciating no matter what the position. Examination is well nigh impossible because of the extreme discomfort any motion of the affected extremity or back produces. The neurologic symptoms and signs are usually outstanding. Procrastination and conservative treatment fail to give relief unless eventually the function of the nerve root is destroyed through pressure. Early operation will not only provide a much appreciated relief

but will prevent serious permanent cauda equina damage. At operation a large completely herniated lesion is usually the finding in this type of patient.

OPERATION

In all patients in whom the above requirements have been fulfilled, exploration of the involved disc is indicated. If this proves negative, certainly the associated disc spaces should also be explored. Many surgeons believe that the disc spaces of both L4 and L5 should be routinely explored as double discs are reportedly not uncommon findings. It is not our purpose to discuss the technic of exploration in this paper. One of the major questions arising, however, will be whether or not a concomitant spine fusion should be performed. At the present time this problem is under discussion in many places. In the early experience with disc operation, only a relatively few patients received spine fusion. In studying end results, various series have been reported up to 50 per cent recurrence of back pain in which this has been the routine. There has been, therefore, a swing of feeling in favor of early fusion but the issue is by no means settled. Many believe that in the young, healthy adult in whom *x*-rays reveal no bony change from the normal, fusion should be omitted, and the patient allowed the briefer hospitalization afforded by simple exploration and excision of protruded disc material, reserving fusion for those patients only in whom *x*-rays indicate definite disc narrowing or in whom degenerative arthritic change is already apparent. It is our opinion that even with simple exploration without fusion the patient should have activities restricted for a longer period than has been customary in the past to allow repair changes to mature in the operated intervertebral disc and thus prevent possible recurrence. With the development of new technics of spine fusion which will be discussed briefly below, the period of hospitalization required after spine fusion has been materially reduced. We deem it, therefore, a better policy routinely to fuse the vertebrae involved to the sacrum following removal of the disc unless there be some extenuating circumstance of health or economics that makes such a course unwise. The area of fusion, we believe, should be inclusive only of the site of the disc lesion to the sacrum. If the disc be found between L5 and S1, we see no apparent reason for including L4 in the fusion area. The danger of pseudarthrosis in the fusion area must always be borne in mind as a general rule in fusing to the sacrum. The more joints fused the greater this risk.

LOW BACK STRAIN

This non-specific diagnosis indicates soft tissue rather than bony injury localized to the low back and not affecting specific nerve roots, and as such, forms the commonest classification of acute primary back pain resulting from trauma. The condition itself seldom, if ever, requires operative interference as it is particularly amenable to rest. In chronically recurring low back strain, basic underlying structural weakness must be suspected. This will be discussed in another section. The lesion in low back strain is most commonly ligamentous tear of varying severity; the pain is thus localized to the back area to one side or the other or occasionally in the midline. Infrequently, ligamentous injury may be adjacent to neural foramena, the resultant edema producing nerve root pressure and some sciatic radiation of pain. The rapidity of recovery following institution of bed rest will give a clue as to the etiology of such pain. Very rarely fascial injuries may be severe enough to require operative repair. This is seen specifically in herniation of the lumbodorsal fascia which can be diagnosed by the prominent painful mass present at the site of rupture.

STRUCTURAL ANOMALIES

In no part of the human skeleton are variations in bony anatomy more prominent than the lumbosacral region. It is

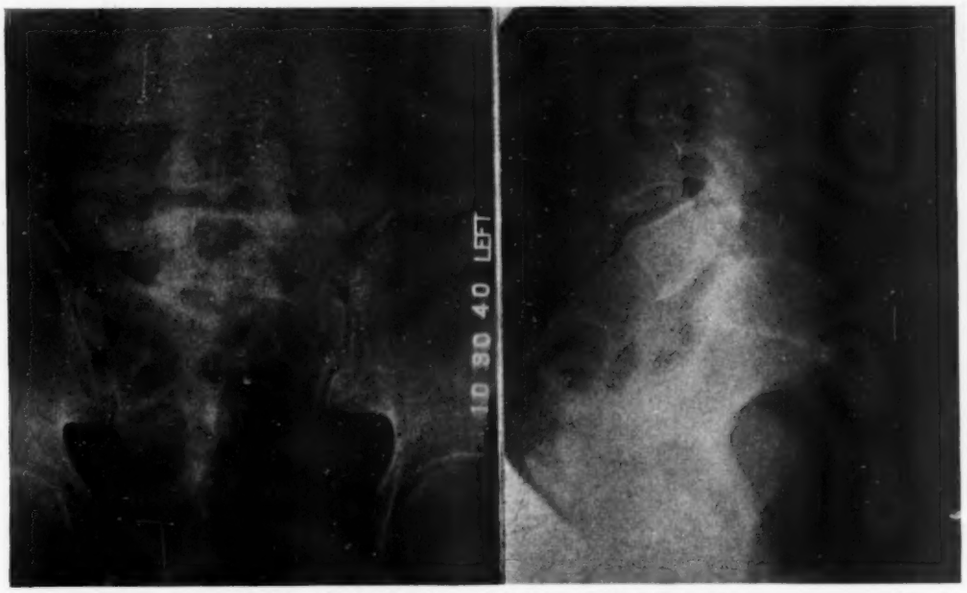

Fig. 2. Congenital variation in the lumbosacral joint. The left transverse process of L_5 is sacralized. There is also a pre-spondylolisthesis.

quite safe to say that no two low backs are exactly alike. These variations show themselves in mild forms as alterations in the thickness of the lumbosacral joint, variations in the angle between the lumbar spine and sacrum or variations in the plane of the small posterior articulations. In more severe instances, transitional vertebrae will be found between those of true lumbar type and those fused to form the sacrum. (Fig. 2.) There may be articulation or fusion of one or both transverse processes to the sacrum or ilium, and the level of the functioning lumbosacral joint is thus elevated. In extreme instances there may be failure of fusion between the ossification centers of the vertebral body to those of the pedicles and laminae producing spondylolisthesis. (Fig. 3.) This occurrence has been estimated as high as 4 per cent by some observers. Rarely, hemivertebrae are seen in this area. These congenital variations are not of importance in themselves unless there is complaint of back pain. There can be no doubt that many people go through life with such changes in a severe degree without ever having back complaint. However, in relation to heavy work and injury, their presence may be of importance as they may be the source of an underlying architectural weakness which will subject the associated soft tissues to strain and injury. It should be noted that these findings become an indication for operation only when there is a history of recurrent back pain not permanently alleviated by conservative measures. Many physicians will probably be of the opinion that spondylolisthesis renders the patient in imminent danger of complete dislocation and paralysis through cauda equina pressure or section. This is by no means true as it is unusual to find more than slight change in vertebral displacement over long periods of observation, even though the patient may be doing heavy labor. The term, lumbosacral instability, is frequently used to classify the milder anatomic changes often seen. It is perhaps better to use a specific diagnosis where possible.

Underlying structural weaknesses in the lumbosacral area may result from (1) Anatomical changes elsewhere, (2) local disease or (3) previous injuries.

Idiopathic or other type of scoliosis at a higher level in the spine will produce a compensatory curve below with unequal distribution of weight and strain upon the lumbosacral joint. Soft tissue contractures involving the back or abdominal muscula-

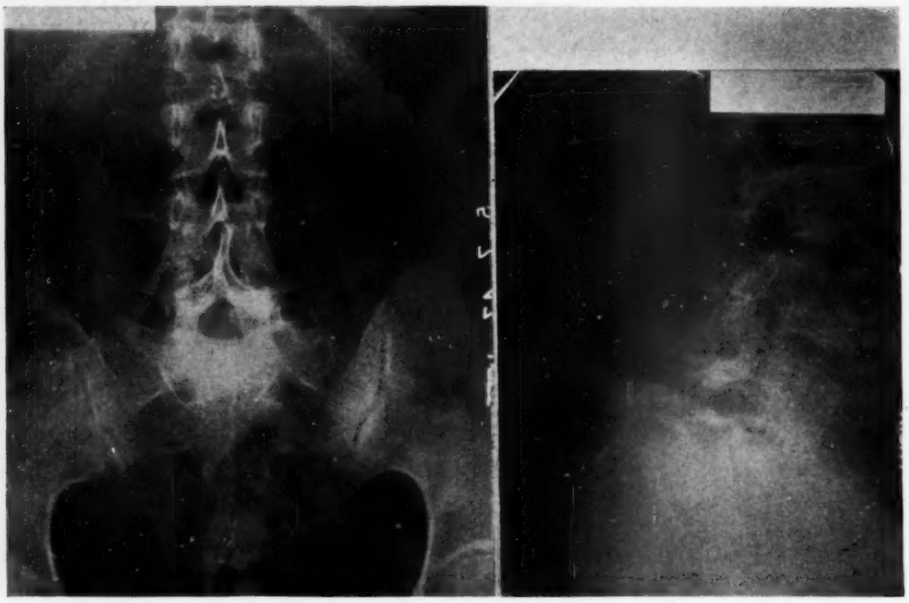

FIG. 3. Spondylolisthesis; L_5 is almost completely displaced anteriorly on S_1.

ture may have the same effect, and a similar mechanical change is produced by differences of leg length which result in pelvic tilting. Joints thus affected are more readily strained than normal ones and may be a cause of recurrent back pain following even mild injury.

Joints or vertebrae that have been previously the site of infection or tumor may be affected structurally producing definite mechanical changes in relation to the soft parts; articulations affected by previous arthritis may represent a weak point, and involvement of a joint during the growth period by an epiphysitis may produce similar change.

Joints previously involved in severe trauma are thus weakened and may develop changes of a productive arthritis with the passage of time. This trauma may have resulted in either ligamentous or disc injury or fracture. The residual joints will not have normal mobility as a rule and will either be a source of recurrent strain from trauma or place excessive strain on surrounding structures with resultant pain. The operation of choice in any condition producing instability is again spine fusion of the involved parts. When this is in the low back, it is usually wise to have the sacrum included in the fusion, thus avoiding excessive strain on the lumbosacral joint even though it may not be involved.

THE FACETTE SYNDROME

This term is used to designate instability of one of the small posterior articulations in the spine. It occurs largely in the lumbar spine, usually in the lower vertebrae. The small posterior articulation on one side or the other as a result of trauma may either be subluxated or actually dislocated. The patient while straining feels a distinct and almost audible and snapping sensation, has immediate pain and finds that he has severely listed and flexed. There is local back pain, usually paravertebral, at the site of the lesion and there may or may not be radiation of pain either into the groin or along the course of the sciatic nerve. Should the lesion be only a subluxation, the patient will find that on rest, posture will gradually return to normal. If a true dislocation has occurred, he will rarely be able to attain reduction by his own efforts. The injury, of course, is primarily a ligamentous one, but in time there should be distinctive changes noted in *x*-rays of the joint involved. Oblique views, in many instances, will provide the diagnosis even

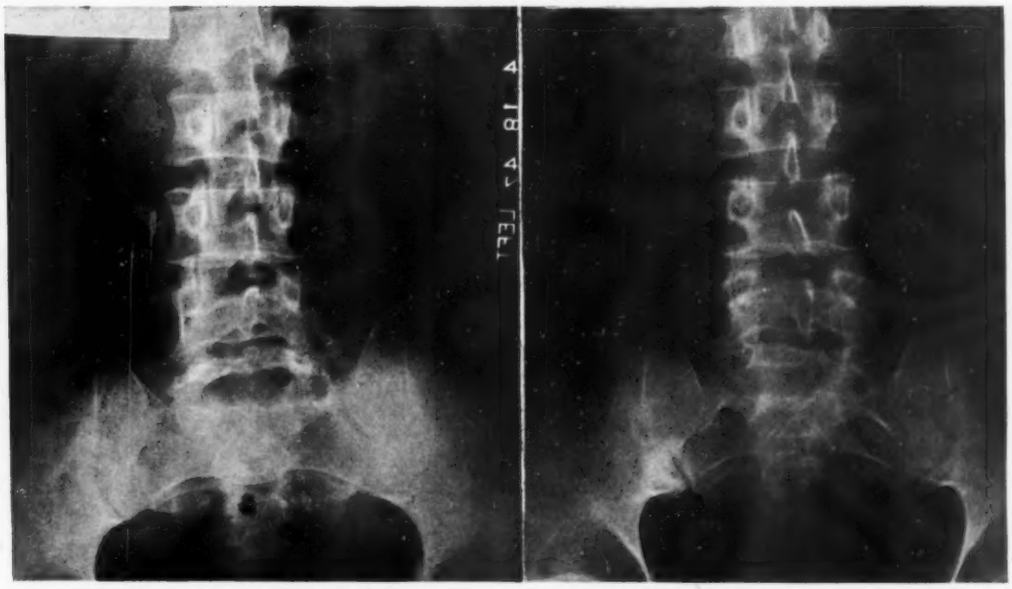

FIG. 4. Early Marie Strumpell arthritis occurring in identical twins at twenty-one years of age. Early changes are present in the sacroiliac joints. (Courtesy of Dr. R. H. Freyberg.)

though dislocation is not actually present at the time of examination. The facet space will be narrowed and may present hypertrophic changes not present in other areas of the spine. Nerve root pressure is produced through both mechanical narrowing of the foramen of exit of the spinal nerve, and resultant edema in the associated soft tissue. In the earlier phases, reduction and a careful trial of conservative treatment are usually successful; and if treated at the primary occurrence, permanent relief is common. If the condition, however, becomes recurrent, spinal fusion operation is the treatment of choice. This diagnosis does not seem to be made as frequently as a few years back, and it is probable that many cases thought to be facet syndrome were in reality disc lesions, especially those in which the disc had protruded itself in or near the neural foramen. Where doubt of diagnosis exists, exploration of the disc should no doubt be done accompanied by a foramenotomy if necessary.

SACROILIAC TRAUMA

The diagnosis of sacroiliac slip or strain is no longer the catch-all that it was just a few years ago. It is made still, however, with far greater frequency than it warrants. The sacroiliac joint is without doubt one of the strongest articulations in the human skeleton. Its ligaments are powerful and numerous. It is doubtful that any but the most severe injuries will affect this joint. This is borne out by the findings in motor accidents where shearing force is placed upon this joint. It is most usual to find a fracture through the ilium rather than a dislocation of the joint itself.

The sacroiliac joint that has been involved by infection, arthritis or epiphysitis, however, represents a different problem and frequently may be the cause of recurrent back pain associated with mild trauma. Changes related to injury must not be confused with early Marie Strumpell spondylitis, as it will be recalled this disease produces its first lesions in the sacroiliac joints. (Fig. 4.) Clinically the shearing test or compression of the pelvis as described above will indicate a localized pain over one or both sacroiliac areas. *X*-rays, especially oblique views of the sacroiliac area will readily support the diagnosis. The blood sedimentation rate may be of differential value. Where disability is sufficient or recurrence is frequent, operation is again the treatment of choice,

FIG. 5. Postoperative roentgenogram illustrating the use of both the spinal plate with bolts through spinous processes and the facet screws as internal fixation. A massive iliac graft and bone chips provide the osteogenic basis of solid bony fusion.

sacroiliac fusion being the most effective. Before doing this procedure, however, careful studies must be directed to the lumbar spine to rule out any concomitant pathologic condition in that area. If necessary, a trisacral fusion may be done at one operation.

OTHER PROBLEMS

There are certain patients in whom low back pain will be a cause of disability where no specific anatomic diagnosis can be made. They may present mild postural changes and will show sufficient muscle contracture and spasm to indicate that the complaint is not entirely subjective. Neurologic and roentgenologic studies will be consistently negative but conservative treatment will fail in its aim to give permanent relief. In some instances, we have demonstrated excessive motion of L5 on S1 as seen in the lateral projection with a slipping of L5 backward at this point. We believe that a diagnosis of true lumbosacral instability may apply and with the failure of conservative treatment, fusion operation should be undertaken. In all patients, no matter what the indication, a careful evaluation of the psychic factors involved must be made. This probably represents the difficult problem for the orthopedist. Psychosomatic factors in relation to the low back are assuming ever increasing recognition at the present time, and it may be safely said that no back pain is without its psychic manifestation. Add to these, the problems of compensation or liability, and the decision as to whether or not to operate becomes exceedingly difficult. Rapid decisions in this regard are, therefore, not to be taken, as the faithfulness of the patient in doing exercises and his general behavior over a period of observation will give much desired information in this regard. Where these factors are prominent, a successful fusion will seldom give complete relief.

TYPE OF SPINE FUSION OPERATION

Since the original work of Albee and Hibbs on the subject of spine fusion, there have been many modifications developed in technic which for the most part have been relatively unimportant as far as successful fusion was concerned. As experience with the procedure and increased knowledge of the status of bone transplants has been obtained, certain basic rules have become increasingly apparent and modifications based on these principles promise an improved percentage in good end results. With the addition of two methods of secure internal fixation in spine fusion, either spine plate or facet screws, the prolonged postoperative immobilization required of simple grafting methods is overcome. (Fig. 5.) We believe that in those instances in which internal fixation is not available immobilization of from eight to twelve weeks in a plaster spica is essential to overall success. Spine fusion with internal fixation requires no immobilization in plaster if the fixation is demonstrably secure during surgery. It has

been aptly demonstrated that bone healing is most rapid when cancellous material rather than cortical bone is employed. Therefore, except in those cases in which a rigid bone graft is desired, the ilium is the donor site of choice. With the proper development of the bone bank, the source of bone transfers will be greatly simplified. Spine fusion itself must always be a serious undertaking and the surgeon must do a thorough and painstaking procedure if he is to assure success.

CONCLUSIONS

It has been our purpose in this paper to present the operative indications in low back states resulting from injury. The important elements of history and physical examination have been reviewed and some specific lesions discussed. Throughout we have stressed the importance of care in observation during both clinical examination and of special diagnostic aids before a surgical program is undertaken.

WHEN the spinal cord is divided completely, and if the patient survives, the immediate effect on the bladder is paralysis and retention of urine. In gunshot wounds of the spine the cord is often cut across or is pulverized by the missile; in other instances the same effect is produced by forcible impaction of a piece of bone.

From "Surgery of Modern Warfare" edited by Hamilton Bailey (The Williams & Wilkins Co.).

COMMON SHOULDER INJURIES*

DIAGNOSIS AND TREATMENT

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COMMON shoulder injuries are simple problems when treated by a program founded upon a knowledge of the normal functional anatomy of the part. However, the therapeutic program must be tempered by a clinical philosophy which includes comprehension and acceptance of certain proven truths pertaining to the shoulder mechanism:

1. The only useful functions served by complete immobilization or partial restriction of function of the injured adult shoulder include: (1) local rest of recently damaged tissues, (2) protection against additional damage and (3) maintenance of bone to bone apposition when aiming for scapulohumeral arthrodesis in the position of maximum function.

2. The inevitable harmful function served by immobilization or restriction of function is the production of a rapidly progressive muscular imbalance, atrophy, stiffness of the joints and prolonged pain and disability.

3. Improper treatment often imposes a more severe penalty upon the patient than would a complete absence of treatment.

4. Considerable derangement of any single motor skeletal component of the shoulder is possible without significant interference with total function.

5. The most important single factor predisposing to unsatisfactory results in common injuries of the shoulder is the utilization of therapy based upon the anatomical or *x*-ray characteristics of the injury to the exclusion of all other factors. The presence or absence of normal anatomy, while desirable, is not especially important to the proper functioning of the shoulder mechanism.

FRACTURES AT THE UPPER END OF THE HUMERUS

Diagnosis. Gross deformity demonstrable by clinical evidence is frequently absent, obscured by swelling or difficult to palpate in the presence of acute pain and spasm. All injured shoulders deserve *x*-ray examination. Adequate roentgenographs demonstrate not only the exact level and extent of the fracture but also the presence or absence of associated complicating features. An anteroposterior view is essential. It is often difficult to obtain a good lateral film of the acutely injured shoulder. However, if a film is taken with the patient standing and the anterior aspect of the injured shoulder against the cassette at such an angle that the central ray parallels the spine of the scapula, a very satisfactory oblique view may be obtained. In thin patients a film taken through the thorax may provide a very adequate true lateral view of the lesion. One or the other is essential to demonstrate accurately the degree of anterior or posterior displacement present and to evaluate the relationship of the fracture fragments to each other and to the scapula.

All objective evidence should be evaluated and certain tests carried out in every case:

1. *Neurological and Vascular Status of the Extremity.* The functional integrity of the brachial plexus and the vascular mechanism always should be evaluated. This requires not more than a few seconds in the average case. If the patient is able to flex his fingers, extend the wrist and spread the fingers apart the median, radial and ulnar nerves, respectively, are intact. In any

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case of doubt sensory examination should be done to confirm or exclude the presence of nerve involvement. The sensory function of the axillary nerve should be tested by pinprick over the skin of the deltoid area. Hypesthesia rather than anesthesia is to be expected if the nerve is damaged. In the presence of an acute injury motor function of the axillary nerve (deltoid muscle) is usually precluded by pain, but it is seldom difficult to appreciate the presence of muscle tone sufficient to indicate that the motor power of the nerve is intact. Vascular integrity should be established by evaluation of the pulse or nail bed circulation, using the normal extremity for comparison. Negative as well as positive findings should be recorded at the original examination for the protection of both doctor and patient.

2. *Swelling.* Swelling is the most accurate available measure of the extent of soft part damage. The amount of soft part damage varies directly with the speed and degree of swelling and the tension of the tissues. Upon this evaluation should depend the decision to give casual or intensive physical therapy designed to eliminate the locally toxic products of pathological conditions of the soft parts.

3. *Ecchymosis.* Ecchymosis occurs late, usually three to seven days after the injury. At this time it is seen just proximal to the elbow on the medial aspect of the arm and at times on the medial wall of the axilla. Early ecchymosis over the deltoid area indicates laceration and perforation of muscle and fascia by a bone fragment. This should immediately arouse suspicion of interposition of soft tissues between the fragments which may be confirmed or ruled out by the absence or presence of bony crepitus at the fracture site. If crepitus cannot be obtained, one attempt at closed reduction may be warranted; but if this is unsuccessful or unduly difficult, the procedure of choice is an operation for removal of the interposed tissue and open reduction of the fracture. Repeated unsuccessful attempts at closed reduction accomplish no good and each does considerable additional damage to the soft part components of the shoulder mechanism.

4. *False Motion or Impaction at the Fracture Site.* Before a treatment program is decided upon it should be ascertained whether there is false motion between the bone fragments or whether they are impacted sufficiently to move in unison. In order to make an accurate estimate the examiner should stand behind the injured shoulder, place one hand lightly on top of the shoulder so that the finger tips rest on the humeral head just anterior to the acromion and grasp the flexed elbow of the injured extremity with his other hand. As the elbow is then gently rotated to and fro the presence or absence of motion of the humeral head in concert with the shaft may be palpated accurately. This technic of examination is emphasized because adequate palpation of the humeral head from the front or side is extremely difficult and often impossible.

5. *Bony Deformity.* Gross bony deformity is uncommon. Usually the bone ends remain in contact. When complete displacement exists the deformity follows a consistent pattern. The upper end of the shaft fragment is pulled medially and forward by the pectoral muscle. Overriding results from the pull of the long muscles of the arm. Shortening is measured by a comparison of the distance between the acromion and the lateral epicondyle with that of the normal side. Medial and forward displacement is apparent on visual comparison of the long axis of the arm with that of the normal side.

TREATMENT

The penalty of improper treatment is greater than that of the untreated fracture. Lesions of the upper humerus take place through vascular cancellous bone. The surgical neck and either or both tuberosities may be involved and at times an intracapsular fragment of the head may become separated from the parent bone. Classification of upper humerus fractures according to location is of little or no therapeutic

significance. As a group they may be divided into two main categories, those requiring reduction and those that do not.

Lesions not Requiring Reduction. This group, with infrequent exceptions, includes all fractures of the upper end of the humerus in which the bone fragments remain in contact. This statement is based upon critical analyses of the end results in a large number of cases treated by various methods and has been substantiated by the accumulated experience of many authoritative clinics. The basis of its validity rests upon the following facts:

1. Bony healing is rapid and certain regardless of the type, presence or absence of treatment.

2. Excellent function is to be expected despite bony deformity. This fact is at complete variance with the statement of Watson-Jones that failure to correct deformity results in limitation of motion by a degree corresponding to that of the deformity. Careful analysis of a large series of adequately followed cases demonstrates conclusively that bony deformities *per se* in the upper end of the humerus have little, if any, functional significance.

3. Prolonged stiffness and disability, a certain amount of which often proves permanent, result from immobilization.

4. Immobilization is unnecessary to maintenance of position. The fragments are stabilized sufficiently by the long biceps tendon and the remaining intact soft part attachments so that displacement further than that incurred at the time of injury rarely occurs. The weight of the dependent arm provides enough traction to maintain axial alignment of the fracture. Impaction is common and even when this is not present at the start, union sufficient to enable all fragments to move in unison usually occurs within two weeks.

Comprehension of these four well proven facts simplifies the therapeutic problem considerably. Since reduction and immobilization is necessary neither to bony union nor function the optimum treatment has only to provide the following: (1) Relief from pain; (2) protection against further damage; (3) maintenance of function of the soft part components of the shoulder mechanism. The following program adequately accomplishes these objectives:

The extremity is dressed in a sling and bound to the thorax by a swathe to provide protection, local rest of the injured tissues and relief from pain. The sling should be applied so that it suspends the extremity at the wrist rather than the elbow, thereby allowing the weight of the arm to act as a beneficial traction force. The weight of the arm alone provides sufficient traction for all fractures at or proximal to the surgical neck of the humerus. The use of a hanging plaster is unnecessary and detrimental to a good result. The swathe should bind the arm to the chest snuggly enough to restrict painful motions during the early stages, but except when required for protection against external forces beyond the patient's control it should be discarded as soon as symptoms permit. Aspirin, codeine, gentle local heat, sedative massage and any other soothing measures available are useful to control pain and spasm, especially during the first week following injury. It should be explained to the patient that any restricting dressing applied is for support, protection and comfort and not designed to immobilize the arm; and that the resultant restriction of motion is a necessary disadvantage of the early stages of therapy which must be compensated for by added effort on his part as soon as diminishing symptoms permit gradual progressive resumption of motion.

Active, gravity-free motion is possible and should be started within a few days or as soon as pain permits. All dressings are removed and the arm allowed to hang at the side. The patient then is made to bend forward with the arm still hanging limp. Gradually, gently, but in a progressively increasing arc, he is instructed in swinging the dependent arm pendulum fashion. As the symptoms subside the scope

of these pendulum exercises are increased. Pain is the accurate measure of safety in evaluating the degree of activity to be permitted at any stage. Further displacement will not take place without further laceration of the surrounding soft part stabilizers of the bone fragments. Any strain sufficient to jeopardize these structures is signalled by pain. So long as motions and exercises are maintained within pain limits there is no danger of increasing the existing deformity.

Within two weeks symptoms usually subside sufficiently to make pendulum exercises free and fairly comfortable. By this time the fragments are healed enough so that clinical examination demonstrates them to move in unison if this was not true at the onset. Gradual progressive resumption of aided active elevation against gravity then should be instituted. This may be done by teaching the patient how to crawl up the wall, and to throw a rope over a door, a shower rod or a pulley and carry out gibbett exercises. Coincident with subsidence of pain and the progressive recovery of function every effort should be directed toward resumption of normal use of the extremity within pain limits. Normal use which calls for synchronized action of the shoulder muscles is much more efficient than any prescribed exercise and should always be started at the earliest possible moment and gradually but progressively increased in scope. As soon as the symptoms permit the sling and swathe should be discarded for progressively increasing periods and then left off altogether except when needed for protection against external forces and when he is asleep. The absence of pain and the recovery of function indicates the time when full normal activities are permissible. The *x*-rays should be ignored in making this decision.

Fractures Requiring Reduction. These fractures include lesions with complete displacement, i.e., no contact between the fragments, and an occasional grossly angulated lesion at the surgical neck.

Reduction. The typical deformity consists of a displacement of the proximal end of the shaft fragment forward and into the axilla with some degree of overriding. The proximal fragment or fragments usually remain relatively unaffected by muscle pull. Displacement of the distal (shaft) fragment results primarily from the action of the long muscles of the arm and the pectoral group. Neutralization of both offending forces is necessary to reduction. The pectorals are in maximum relaxation when the arm is flexed and adducted. Traction is necessary to overcome the pull of the long muscles of the arm and restore the length of the humerus. Therefore, if bone length is restored by traction in the flexed and adducted position, completion of the reduction by manipulative eradication of the displacement caused by the pectorals becomes a simple maneuver. Attempts to reduce the deformity described above with the arm in any position other than flexion and adduction are contrary to the anatomical factors involved and very apt to be unsuccessful.

Failure to obtain a satisfactory reduction on one, or at the most two, technically adequate attempts usually is indicative of interposition of soft tissue structures between the fragments. Open reduction should then receive prior consideration over further manipulations which are no more likely to be successful than the first attempt. Each additional manipulation, no matter how expertly it is carried out, creates considerable additional soft part damage which may be followed by more disastrous results than the primary lesion. It is probably safe to say that any lesion which requires repeated forcible manipulations is either being reduced improperly or is characterized by some unrecognized complicating factor which precludes reduction by manipulative methods.

Maintenance of Reduction. Whenever possible reduction should be followed by an attempt to impact the reapposed fragments by manual compression in the long axis of of the bone applied at the elbow and

shoulder. After this has been accomplished, or even if the attempt to impact has failed, the arm should be gently brought down to the side from its reduction position of flexion and adduction. If bony contact remains with the arm in a dependent position, treatment may proceed along the lines discussed for fractures not requiring reduction.

If loss of contact between the bone ends recurs when the arm is brought to the side, more energetic measures for maintenance of reduction become necessary. These must provide maintenance of normal bone length and relaxation of the pectoral muscles. An efficient method of accomplishing these two objectives consists of skeletal traction by a Kirschner wire through the olecranon with the patient in bed and the arm flexed and adducted. More than ten days of bed rest and maintenance of reduction by such a program is rarely necessary before clinical examination demonstrates the fragments to move in unison as the arm is gently rotated. The traction then may be removed, the arm brought to the side and the lesion treated by a program identical to that described for similar fractures not requiring reduction.

Isolated Fracture of the Greater Tuberosity. This lesion is common and often overtreated. So long as the tuberosity fragment remains in contact with the parent bone it is without therapeutic significance and should not be treated as a fracture in the usual sense. Nothing by symptomatic therapy is required. Continuance of function up to pain limits should not only be permitted but insisted upon. A sling should be used no longer than is necessitated by pain. Recovery is rapid and in the absence of associated intrinsic tendon damage usually is complete.

ANTERIOR DISLOCATION OF THE SHOULDER[3,8,10,11]

Diagnosis. Clinical diagnosis of the dislocated shoulder is simple if the lesion is looked for. Inspection always shows an abnormal deviation of the long axis of the humerus as compared to the normal side. Viewed from in front the long axis deviates toward the base of the neck, and as inspected from the side it passes anterior to the acromion. These abnormal phenomena are always apparent even in the most obese patients. The normal rounded contour of the shoulder is replaced by a flattened deltoid hanging from an unduly prominent acromion process, but this appearance may be obscured by obesity or local swelling. In thin patients the infraclavicular fossa often is obliterated or replaced by a bulge caused by the displaced humeral head. The absence of the humeral head from its normal subacromial position almost always is palpable.

Certain other tests of importance should be done in every case:

1. Pinprick evaluation of skin sensation over the deltoid. Approximately 30 per cent of anterior shoulder dislocations demonstrate evidence of axillary nerve damage in the form of hypesthesia in its sensory distribution. Usually this evidence disappears following reduction. If not, management of the neurological lesion in concert with the treatment of the di location becomes imperative.

2. Evaluation of the circulatory status of the extremity and of the functional integrity of the median, ulnar and radial nerves, any or all of which may be involved at the site of the dislocated humeral head.

3. Measurement of arm length from acromion to lateral epicondyle and comparison with the normal. Anterior dislocation produces, if anything, a slight increase in this measurement. Gross shortening should be considered pathognomonic of fracture dislocation with imminent danger of serious damage to the neurovascular structures in the axilla until proven otherwise by *x*-ray.

4. *X*-ray films should be obtained in every case as soon as possible. The majority of complicating factors mitigating against successful therapy by routine methods are present and discernible in pre-reduction films.

Fracture of the Greater Tuberosity. This lesion is present in 25 per cent of anterior dislocations. It is not a complication when the tuberosity fragment remains in approximately normal position and embedded in the empty capsular sleeve from which the humerus has dislocated. (Fig. 1.) Under these conditions reduction of the dislocation results in spontaneous anatomical reposition of the tuberosity fragmen- which then may be disregarded completely during aftercare of the case. Occasionally the tuberosity fragment is seen to be retracted up under the acromion. (Fig. 2.) Such a circumstance is pathognomonic of a massive avulsion of the short rotator tendons from the head of the humerus. This is a crippling lesion and operative intervention is indicated at an early date if a useful shoulder is to be regained.

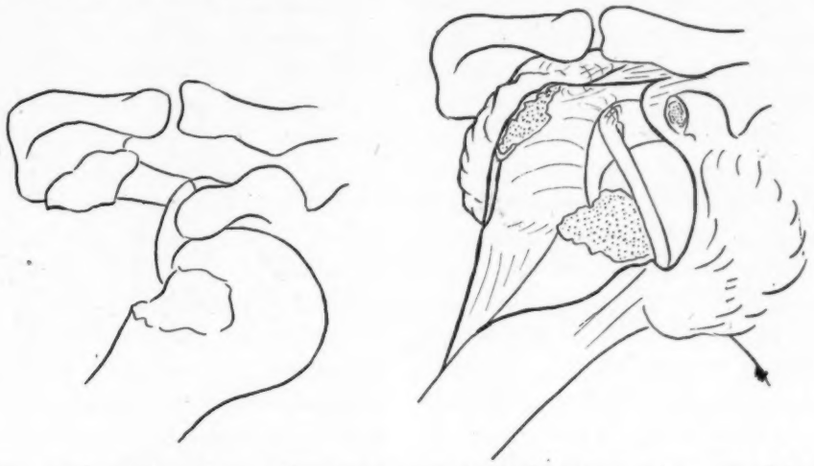

FIG. 1. Left, tracing of *x*-ray film showing anterior dislocation and fracture of the greater tuberosity. The fracture fragment remains in approximately normal position; right, the anatomic defect accounting for the wide displacement of the fracture fragment and its spontaneous reposition upon reduction of the dislocation.

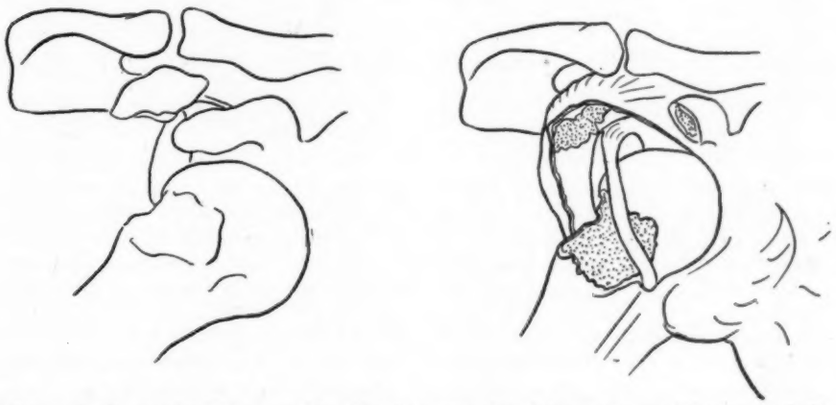

FIG. 2. Left, tracing of *x*-ray film showing anterior dislocation and fracture of the greater tuberosity. The fracture fragment is retracted well up under the aeromion; right, the anatomic equivalent of a massive avulsion of the intrinsic tendons from the humerus accounts for this phenomenon and for the failure of fracture reposition to occur when the dislocation is reduced. Early operative repair is indicated.

Occasionally the tuberosity fragment accompanies the humeral head. (Fig. 3A and B.) Such a lesion rarely is characterized by spontaneous accurate replacement of the fracture fragment following reduction of the dislocation. Intrinsic tendon damage usually is present and should be repaired as soon as significant symptoms and disability

prove persistent. Intrinsic tendon damage is the lesion most commonly encountered in dislocations whose post-reduction courses are painful and prolonged. Occasionally a large tuberosity fragment extends forward to involve the bicipital groove.

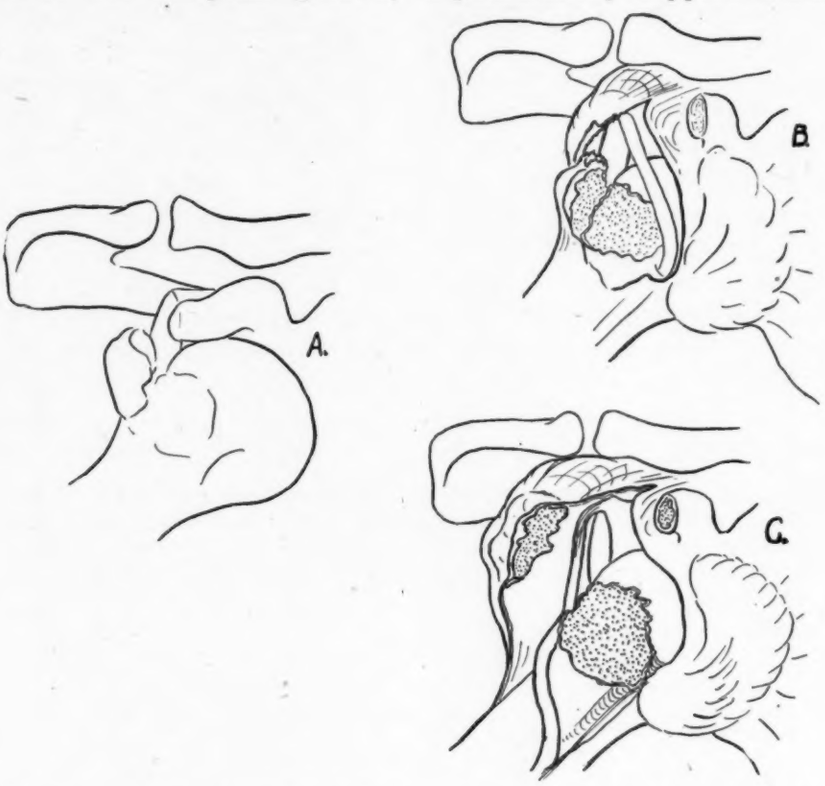

Fig. 3. A, tracing of *x*-ray film showing anterior dislocation and fracture of the greater tuberosity. The fracture fragment has accompanied the humeral head into its dislocated position; B, the anatomic defect frequently accounts for the position of the tuberosity fragment in A., i.e., a partial or complete avulsion of the cuff fibers from the fragment. This lesion should be suspected whenever reduction of the dislocation is not accompanied by accurate reduction of the fracture; C, when the tuberosity fracture involves the bicipital groove the biceps tendon may slip backwards to assume a position behind the humeral head, very effectively preventing closed reduction of the dislocation.

When this occurs the biceps tendon may slip backward from the groove and come to occupy a position behind the dislocated humeral head, very effectively preventing reduction. (Fig. 3C.) Failure to reduce, or persistent re-dislocation immediately following reduction should warrant early exploration and replacement of the biceps tendon. Repeated closed reductions or unsuccessful attempts to reduce are strongly contraindicated.

Fracture of the Humeral Head or Neck. Fracture of the surgical or anatomical neck of the humerus is an uncommon but dangerous complication. The risk of serious brachial plexus damage is always present and a single unguarded motion or ill advised forceful manipulation may produce a permanently crippled extremity. Closed methods of reduction designed to reduce both the fracture and the dislocation are often unsuccessful. Operation with reduction or excision of the head fragment carried out under direct vision is the therapy of choice when gentle manipulation fails to provide satisfactory restoration of anatomy.[8]

Reduction of Uncomplicated Dislocation at the Shoulder.[11] The so-called "heel in the axilla" maneuver for reduction of anterior dislocations of the shoulder is to be strongly condemned. It is neither safe nor

necessary for use as a routine procedure. The "Kocher" maneuver as it is generally used has become a manipulative procedure designed to force the humeral head back into the glenoid fossa. In late reductions when the glenoid cavity is partially filled by blood clot and the surrounding musculature has lost its normal elasticity such a procedure may be warranted as the only method for obtaining a closed reduction. In early lesions the procedure is unnecessary and potentially dangerous.

The safest and most efficient method of reduction consists of steady traction in the axis of the adducted humerus under adequate anesthesia. Countertraction by gravity or a thoracic swathe may be required. If the traction is steady, the majority of dislocations reduce without further manipulation within sixty seconds. When this fails to occur traction should be continued for several additional minutes after which a gentle rotary motion of the humeral shaft or a lateral push against the displaced humeral head almost always will be followed by restoration of anatomy. This method of reduction is not only safe but will be successful in all early cases adequately anesthetized unless there exists an unrecognized complicating factor which precludes reduction by closed methods.

After-treatment. Once reduction is accomplished optimum after-care must provide: (1) protection against re-dislocation (2) comfort and (3) maintenance of function. Usually the discomfort is minor in degree. Maintenance of motion and function is always possible without undue risk of redislocation. The speed and degree with which function may safely be resumed depend upon the ease of the reduction. The more rapidly and easily a dislocation is reduced the more easily will it re-dislocate and vice versa. Re-dislocation, however, becomes a significant danger only when the arm is elevated against gravity. Normal progressive use of the arm in the dependent position is possible and safe from the start. A safe equivalent of motion in the elevated position can be maintained by a program of gravity-free pendulum exercises done in the stooped position. A sling and swathe is adequate protection against re-dislocating forces of external origin. This should be worn while sleeping for at least a month. With a responsible cooperative patient the dressing may be left off during the day at all times when he can voluntarily refrain from active elevation. Strenuous activities even with the arm dependent should be restricted for several weeks. The average case may be allowed use of the arm in all positions below 45 degrees of abduction throughout the first two weeks and below 90 degrees throughout the second two weeks. Progressive resumption of use in all elevated positions is then safe. In irresponsible or uncooperative patients the arm should be dressed in a sling and swathe for at least several weeks and the penalties of such restriction of motion (prolonged but not usually permanent stiffness) accepted as unavoidable. Healing takes place or not regardless of the type of treatment provided re-injury is prevented. Habitual dislocation results from re-injury or specific intrinsic damage and is otherwise unrelated to the treatment of the primary lesion.

INTERNAL DERANGEMENT OF THE SUBACROMIAL MECHANISM

The subacromial mechanism is bounded above by the acromion and the coracoacromial ligament and below by the head of the humerus. Its component structures include the subacromial or subdeltoid bursa, the musculotendinous cuff, the articular capsule of the shoulder joint and some loose areolar tissue. The intra-articular portion of the long biceps tendon, although functionally unassociated, is in close proximity to these structures and is to be considered as a potential etiological factor in the production of subacromial derangement.

All subacromial lesions are prone to involve secondarily the subdeltoid bursa and produce the clinical syndrome generally recognized and treated as "subdeltoid or subacromial bursitis." The almost universal acceptance of this term

as the diagnosis upon which therapy is to be based constitutes the most important single factor mitigating against successful management of the painful or stiff shoulder. "Bursitis," as an all inclusive term denoting the diagnosis and basis for therapy in the painful shoulder, is as irrational as would be peritonitis for pain in the abdomen. Both are clinical syndromes resulting secondarily from some primary focus of irritation. Rational therapy demands identification and management of the primary lesion.

I. *Differential Diagnosis of Painful and/or Stiffened Shoulder*

1. Intrinsic lesions affecting the subacromial mechanism:
   - (A) Calcific deposit in the short rotator tendons
   - (B) Adhesive capsulitis (idiopathic frozen shoulder)
   - (C) Rupture of the musculotendinous cuff
   - (D) Arthritic changes in acromion and humerus
   - (E) Infection, originating in the bursa
   - (F) Rheumatoid arithritis involving the bursa

II. *Extrinsic Lesions Simulating Bursitis but Usually Affecting the Shoulder Joint Mechanism*

- (A) Disuse due to any cause
- (B) Internal derangement of the acromioclavicular joint
- (C) Neurological lesions of cervical or peripheral nerve origin
- (D) Adjacent infection (bone or joint)
- (E) Bone neoplasm (usually humerus)
- (F) Rheumatoid arthritis
- (G) The formation of adhesions, post-traumatic

CALCIFIC DEPOSITS IN THE SHORT ROTATOR TENDONS[1,3,4,5,6,8]

Diagnosis. Subdeltoid bursitis secondary to inflammation centered around a calcific deposit accounts for approximately two out of every three painful shoulders encountered in the United States. Adequate *x*-ray films demonstrate the presence, location, size and consistency of the deposits. Similar quiescent deposits are to be encountered frequently in *x*-ray films of asymptomatic shoulders. The diagnosis, therefore, cannot be made upon the basis of *x*-ray evidence alone.

Little difficulty is to be encountered in identification of the acute case. In addition to the *x*-ray findings there is constant and severe pain in the shoulder, aggravated by motion and little relieved by rest. There is wincing tenderness over the bursa which may be swollen and even fluctuant, and this is exquisite at the site of the inflamed deposit. A mild systemic reaction may be present and the effects of pain and loss of sleep usually are obvious in the patient's face. Clinically the acute lesion requires differentiation only from acute infection and recent trauma. The history usually excludes the latter while the former is ruled out by the great disparity between the severity of the local reaction and the relative mildness of the systemic response.

The chronic lesion may be much more difficult to identify with certainty due to the frequency with which incidental quiescent deposits are encountered in *x*-rays of non-painful shoulders. It may be assumed with reasonable certainty that if a deposit is present by *x*-ray there is little or no possibility that the tendon cuff is ruptured. Several hundred operations for removal of calcific deposits and a similar number of cuff tears repaired by operative means disclosed only one patient to have both lesions simultaneously. The remainder of the lesions to be differentiated should be excluded prior to deciding that the deposit seen by *x*-ray is the cause of a chronic painful shoulder. In the appropriate age groups early bone neoplasm should be suspected in any case which responds abnormally or fails to respond to routine sedative measures over a protracted period. A secondary syndrome resulting from

chronic muscle spasm is common in the chronic case of more than a few weeks' duration. As a result, the insertion of the deltoid may be described as the subjective center of pain. Radiating pain is common in the arm, forearm and even the fingers and often involves the posterior scapular muscles and the trapezius. As a result of constant pain, stiffness and atrophy, the penalties of disuse eventually become superimposed to further complicate the diagnostic problem.

Treatment. Rational treatment of the calcific lesion depends upon comprehension of the following: (1) Eventual spontaneous cure is to be expected regardless of the type, presence or absence of therapy since the disease is self-limiting. (2) Only two types of treatment are available, curative and palliative. Removal of the deposit by operation or aspiration are the only known therapies of proven curative value. All others are purely palliative in nature or empirical in effect. Less than 10 per cent of chronic cases require curative treatment. The remainder are controllable by palliative measures until spontaneous remission or subsidence of symptoms occurs. The only indication for curative treatment in the chronic case consists of symptoms and disability sufficient to make it worth while from the patient's point of view. The patient alone is qualified to decide this point. The only certain curative therapy available for the chronic lesion is removal of the deposit by operation. Rarely is it amenable to aspiration through a needle and there is little or no likelihood of a favorable response to radiotherapy. Palliative therapy includes all sedative measures which reduce pain and muscle spasm. Every effort should be made to maintain the mobility of the arm. Rest or restriction of motion is strongly contraindicated in the chronic case since the inevitable penalty is increased atrophy and stiffness of the shoulder mechanism. Simple home measures such as gentle local heat, aspirin and barbiturates, coincident with frequent active exercises within pain limits are found to accomplish just as much as any of the more widely publicized formal therapies.

In the acute lesion, although the duration of symptoms rarely exceeds seven to ten days under any circumstances, the pain often is severe enough to demand curative therapy. In the presence of acute inflammation the contents of the deposit become infiltrated with exudate and not only change from a dry to a semi-fluid consistency but also develop considerable tension within a closed cavity. Following localization of the lesion by *x*-ray and palpation the treatment of choice is puncture and deflation of the tense deposit by a needle inserted under procaine hydrochloride anesthesia. Some of the material should be aspirated as proof of the successful accomplishment of this objective. The therapeutic principle is identical to that underlying incision and drainage of an abscess. Once the contents of the deposit are allowed to escape from their tendon cavity into that of the bursa rapid absorption and subsidence of the inflammatory reaction is the rule. When this procedure is impractical or unsuccessful operative incision of the deposit may be warranted. The results of radiotherapy, while frequently spectacular, are empirical and similar to the results of adequate local sedation by any other means.

RUPTURE OF THE MUSCULOTENDINOUS CUFF[2,3,7,8,9,10]

Traumatic lesions of the cuff may vary from a rupture of only a few fibers to a complete avulsion of its whole insertion from the humerus. They are classified as complete or incomplete depending upon whether the tear involves the whole or only a partial thickness of the tendon cuff. The diagnostic and therapeutic significance of a cuff injury depends not upon its presence but upon its effect. A large tear may produce insignificant pain and disability while a small lesion may prove extremely painful and completely disabling to the individual.

Exploration is the only certain method for making the diagnosis of incomplete rupture of the cuff. There are four tests for the certain identification of a complete thickness tear. Often none of these tests will be positive in the case at hand and their absence does not rule out the lesion.

1. *By x-ray:* The presence of a retracted fracture of either humeral tuberosity is pathognomonic of a large tear. (Fig. 2.)

2. *By x-ray:* Demonstration of an abnormal communication between the shoulder joint and bursal cavities by the injection of contrast media, e.g., filtered oxygen, makes the diagnosis reasonably certain.

3. *By palpation:* A hiatus in the continuity of the tendon fibers usually is demonstrable by expert and experienced palpation. This test is valid only in the chronic lesion and almost always is precluded by the presence of acute tenderness.

4. *By the demonstration of afunction or dysfunction* of the injured segment of the tendon cuff: One of the important functions of the intrinsic cuff is to stabilize the glenohumeral fulcrum so that the deltoid can maintain the extremity in the abducted position against gravity. Without cuff function the deltoid is powerless. The main duty of carrying out this particular function falls upon that segment of the cuff directly overlying the humeral head, i.e., that portion of the cuff having a mechanical advantage to abduct. The remainder of the cuff is relatively unrelated to the maintenance of abduction. Depending upon the rotation of the arm any of the four tendon components of the cuff mechanism may assume a position directly above the humeral head and be called upon to fulfill this functional demand. It is found that cases characterized by a complete avulsion of the cuff from the humerus are unable to maintain abduction in any position. On the other hand tears less than 3 cm. in length are compensated for by adjacent intact tendon fibers so that no serious functional defect may be apparent except for a relative weakness as compared to normal. Intermediate tears demonstrate inability to maintain abduction when the arm is placed in a position which throws the load upon the torn segment. Maintenance of abduction against gravity or light pressure, therefore, should be tested with the arm passively abducted to the horizontal position and successively placed in all positions of rotation. This test is invalidated by acute pain which often prevents maintenance of abduction even though the cuff be intact, and its results cannot be depended upon for the certain diagnosis of lesions less than 3 cm. in length.

The clinical picture of a cuff tear is characterized by some combination of many other confirmatory signs and symptoms which have been described with great clarity by Codman.[3] It is to be emphasized, however, that all manifestations of the lesion other than the four described above are frequently reproduced by other conditions and not to be considered as pathognomic. Passive restriction of glenohumeral motion, except when produced by pain, may be taken as reasonably certain evidence against the presence of a complete tear. No frozen shoulder explored to date has been the seat of a gross cuff tear (although a few incomplete tears have been found in stiff shoulders), and none of a large series of complete tears proved by operation has been characterized by stiffness. A calcific deposit or stiffness, therefore, makes the possibility of rupture remote.

A definitive diagnosis of cuff tear is neither necessary nor important to the choice of therapy except in the case of massive avulsions, all of which are disabling and warrant surgical repair at the earliest possible moment. All suspected lesions should receive at least three weeks' observation and conservative therapy of a sedative nature. The use of an abduction splint during this time does more harm than good and is strongly contraindicated. Symptoms subside and function returns spontaneously within two to three weeks following injury in the majority of cases. As long as improvement continues, no matter how slowly, conservatism is indi-

cated. There is only one indication for exploration and operative repair. This consists of symptoms or disability sufficient to make it worth while from the patient's point of view. This indication is valid regardless of whether or not a definitive diagnosis can be made. It is to be emphasized that while the diagnosis may be suspected it cannot be made with certainty in many complete thickness tears nor in any incomplete tear. Often a suspected anatomic diagnosis is confirmable only by exploration.

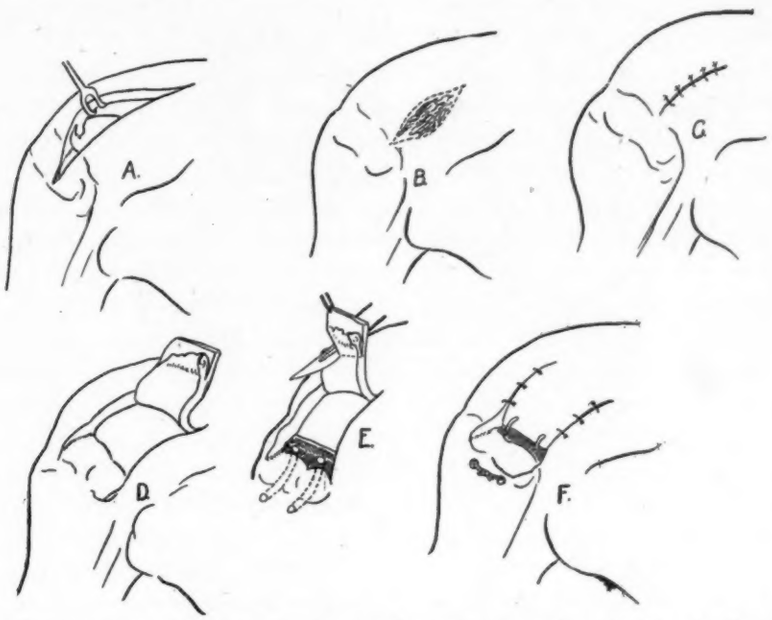

FIG. 4. A, identification of a deep surface tear through an incision in line with the cuff fibers; B, localized area of laceration visualized on the presenting surface of the tendon cuff. Dotted line indicates placement of elliptical excision; C, side-to-side suture of the elliptical defect following excision of B; D, following identification of a deep surface tear as in A, a flap of cuff as wide as the tear is long is elevated from the humeral attachment of the cuff; E, the tear is excised; F, the shortened flap is reinserted into a bony trench in the humeral head and fastened by a mattress suture passed through drill holes in the bone and tied lateral to the greater tuberosity.

Treatment. Conservative therapy is indicated in the great majority of cases for at least several weeks. It should provide: (1) comfort, (2) protection against additional damage and (3) maintenance of function up to the limits of pain and fatigue. A therapeutic program identical to that described for fractures of the upper humerus not requiring reduction is optimum. The great majority of suspected lesions make a complete recovery within two weeks under such a regimen. Many cases characterized by definitive evidence pointing to the presence of a tear also are characterized by spontaneous subsidence of symptoms and recovery of function. Those with persistent residual pain or disability warrant consideration of operative therapy regardless of the presence or absence of a definite diagnosis.

Operative Repair. Adequate exposure is of paramount importance to the success of any operative repair. The deltoid muscle may be split downward from the acromion at any point so long as the split does not extend distalward for more than 3 cm. When a longer muscle incision is necessary it should never be made except at the anterior border of the deltoid or through the deltopectoral interval. A transacromial approach (Fig. 5B) provides the best exposure of the musculotendinous cuff coincident with a good cosmetic result. This

approach utilizes a short anterior deltoid splitting incision which, when necessary for exposure, is carried backward through the acromion process just lateral to the acromioclavicular joint. Excision of the outer fragment of the divided acromion is carried out routinely at the close of the operation in preference to repair of the bone incision.

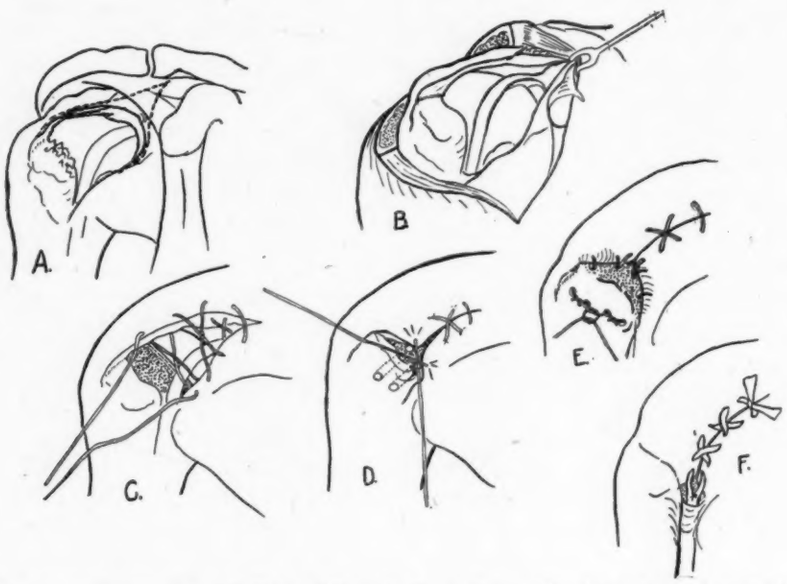

Fig. 5. A, rupture of cuff. Dotted lines indicate lines of incision for removal of damaged tissue in such a way that the residual defect simulates an isosceles triangle; B, exposure of a complete cuff tear through a transacromial approach; C, placement of continuous "shoe lace" suture following triangular excision of the tear. Stippled area indicates the portion of humeral head denuded of cartilage for reinsertion of tendon; D, the suture is pulled tight up to but not past the point of tension with the arm at the side. Drill holes are made through the tuberosity to emerge close to the transposed ends of the tendon flaps; E, additional mattress sutures are required to stabilize the residual edges of the tendon flaps in many tears of 3 cm. or more; F, small tears close to the bicipital groove may be obliterated by autogenous suture using the split intra-articular portion of the biceps tendon which has first been separated from its glenoid attachment.

Incomplete Ruptures. Incomplete thickness tears often remain obscure at operation since if they involve the deep surface of the cuff the floor of the bursa remains intact. This type of tear requires for identification a longitudinal incision through the cuff fibers so that the deep tendon surface may be visualized. (Fig. 4A.) Following identification a flap of cuff insertion as wide as the tear is long should be elevated from the humerus. (Fig. 4D.) The torn portion is excised (Fig. 4E) and the flap reinserted into a bony trench at the anatomical neck and fastened in place by heavy mattress sutures through drill holes in the bone. (Fig. 4F.) Visible areas of localized tendon laceration in the floor of the bursa should be removed by an elliptical excision and the defect repaired side-to-side. (Fig. 4B and C.) In neither repair should there be any appreciable tension upon the reparative sutures and following wound healing the postoperative program may approximate that described for the treatment of upper humerus fractures not requiring reduction.

Complete Ruptures. Since no two tears ever are identical no standardized reparative technic is possible. However, every repair to be successful should provide: (1) restoration of continuity between the intrinsic muscle bellies and the humerus and (2) snug apposition of healthy to healthy tissue without tension at the repair

site. End-to-end or end-to-bone repair rarely is possible in such a way that these prerequisites are fulfilled and the majority of attempts to do so are failures. Follow-up analyses of fractured upper humeri have demonstrated beyond all doubt that the direction, length and point of insertion of any component of the cuff can be altered grossly without detracting from the total function of the shoulder mechanism. The two prerequisites essential to success mentioned above therefore should be fulfilled, if necessary at the expense of normal anatomy. As a general plan of procedure applicable to the majority of complete lesions the edges of the tear are excised back to healthy vascular tissue in such a fashion that the residual defect becomes an isosceles triangle with the greater tuberosity as its base. (Fig. 5A.) The longer the sides of this triangle the easier is the subsequent repair. A continuous shoelace type of heavy suture is implanted in a manner to provide side-to-side apposition of the sides of the triangle (Fig. 5C), up to but not past the point of tension with the arm at the side. The underlying humeral head is denuded of cartilage at the point where side-to-side apposition creates tension upon the suture. (Fig. 5D.) The suture ends then are passed through drill holes in the bone and tied lateral to the tuberosity. Ruptures up to 2 cm. in length can be obliterated completely by this technic. Larger lesions usually require the utilization of additional mattress sutures (Fig. 5E) for stabilization of the residual tendon edges. Certain small tears situated in close proximity to the bicipital groove are amenable to repair by autogenous suture using the split intra-articular portion of the biceps tendon. The tendon is divided at its glenoid attachment and split longitudinally down to the upper end of the bicipital groove. The two halves are then woven, shoelace fashion, through the edges of the tendon defect and tied as in Figure 5F.

Certain massive tears are not amenable to triangular excision and side-to-side repair. End-to-bone repair then becomes mandatory. It is a mistake to attempt reapproximation of the avulsed tendon insertions to the greater tuberosity at a cost of tension. They should be reinserted into the humerus at whatever point they will reach without tension in any manner restoring continuity between the intrinsic muscle bellies and the humerus.

An abduction splint is unnecessary and potentially disadvantageous to the postoperative regimen providing repair has been carried out according to the principles and technic described. Gravity-free motion and function should be commenced as soon as the operative wound has healed, and gradually but progressively increased. Motion and use against gravity should be restricted until such time as seems compatible with solid healing of the repair. The results[9] are very satisfactory.

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PRESENT CONCEPTS CONCERNING THE CARE OF THE BURNED PATIENT*

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BECAUSE significant changes have occurred in the treatment of thermal injuries over the past five years, it seemed desirable to review briefly some of the more recent trends and outline a method of treating burns which has been found to be satisfactory. The treatment of patients with burns can be divided into the following four main categories: 1. The early therapy consisting of the relief of pain and treatment of shock; 2. the immediate care of the local wound and the control of infection; 3. the nutritional and metabolic problems of the burned patient and 4. skin grafting and the prevention of scars and contractures.

EARLY TREATMENT

Immediate treatment of burns should consist of instituting shock therapy as soon as possible and general anesthesia should be avoided. Experimental studies by Elman[1] demonstrated that the mortality rate is definitely increased following the administration of barbiturates and morphine while clinical experience has shown that such compounds should be employed cautiously and only when necessary. Since relief of pain helps alleviate shock some medication for this purpose should be beneficial. Because the circulation is frequently impaired following a burn or injury, morphine given subcutaneously or intramuscularly is often not absorbed and therefore does not relieve pain.[2] Repeated injections may later be absorbed when the circulation has been restored to normal with a resulting morphine poisoning.[3] Because of this, Beecher[2,3] advises giving morphine sulphate, grains ⅙ intravenously to adults and repeating every half hour or so if necessary.

The intravenous administration of 0.1 to 0.2 per cent procaine has been employed for the relief of pain and while there has been little experience with this method, it may offer a suitable way of relieving the discomfort while shock therapy is being carried out. Gordan[4] advises injecting 1 Gm. of novocain crystals in 500 to 1000 cc. of an isotonic salt solution over a period of one to one and one-half hours.

During the past ten years the treatment of shock in burned patients has been largely accomplished by the use of plasma. In the past few years it has been noted both experimentally[5,6] and clinically[7–10] that the use of a sodium containing electrolyte solution and blood is just as effective as plasma and in some respects is preferable. Plasma was advocated primarily because of the osmotic effect of the protein molecule and also because it reduces the existing hemoconcentration. However, it has been demonstrated that there is some reduction in the red cell mass following a burn[11,12] and that hemoconcentration can be overcome and an adequate circulating blood volume maintained if electrolyte solutions are employed.[5–7] Plasma proteins have been shown to be lost from the vascular system at a rate comparable to that of sodium following a burn.[13] Thus, the more recent trend has been toward supplying blood which contains both red cell and protein elements and to maintain the circulation by increasing tissue tension by the administration of an electrolyte solution. In a series of patients treated with large amounts of plasma the edema in the burned

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areas remained for longer periods of time than it did in those patients treated with an electrolyte solution and blood. This probably occurred because of the presence of relatively large amounts of protein in the extravascular spaces of the traumatized area in the plasma treated patients.

Various solutions have been demonstrated to be effective in combating shock[5,7,9,10,14,15] but we prefer a solution which contains inorganic electrolytes in amounts similar to that found in the extracellular fluid. Since additional water should be provided so that good kidney function will occur, such a solution has been administered after diluting it to two-thirds the original strength. Hartman's solution (Ringer-lactate) can be used or one containing 6 Gm. of sodium chloride and 2½ Gm. of sodium bicarbonate per liter. In order to make the latter two solutions hypotonic, 500 cc. of water should be added to 1,000 cc. of an isotonic solution. In many instances the patient will be able to drink this mixture but if it cannot be taken orally due to nausea or vomiting or if it seems that the burn is sufficiently severe so that vomiting might occur, it is wise to administer the solution intravenously until the patient's condition improves.

Since the hematocrit and various other chemical constituents often fail to indicate the amount and type of treatment necessary,[7,16,17] the latter should be governed by the severity of the burn and the size of the individual patient. The extent of the body surface area burned can be determined from the charts advocated by Lund and Browder.[18] The amounts of hypotonic electrolyte solution and blood which have been found to be effective are shown in Table 1.

No hard and fast rule should be used in prescribing therapy but the amounts of the various solutions should be altered to fit the patient's individual requirements and his response to treatment. The authors,[7] as well as others[9] have found that the urinary output provides a valuable guide as to the state of the patient and the effectiveness of therapy. In order that frequent checks can be made it is often desirable to insert a Foley catheter into the bladder of patients with a moderate or severe burn. The urine is then collected into a large graduated cylinder so that the per minute rate of urinary flow can be frequently and easily calculated.

TABLE 1
THE AMOUNT OF 0.6 PHYSIOLOGICAL ELECTROLYTE SOLUTION AND WHOLE BLOOD TO BE USED IN COMBATING SHOCK RESULTING FROM A BURN

Per Cent of Body Surface Burned	The Amount of Hypotonic Electrolyte Solution Given in the First Twenty-four Hours	Amount of Blood Given during First Twenty-four Hours
5 to 15	Amount equal to 6 to 8% of patient's body weight	25 to 50 cc. for every per cent the body is burned or an amount equal to
15 to 35	8 to 12% of body weight	2 to 6% of body weight; (the larger quantities to
35 to 100	12 to 14% of body weight	be given to patients with third degree burns)

When the inhalation of smoke and fumes has occurred it would seem wise to inject an isotonic electrolyte solution into the burned area as advocated by Berman and his co-workers.[15,19] By such a method, tissue tension is increased with a preservation of a normal blood pressure and pulmonary edema is less likely to occur. The amount of whole blood employed should vary somewhat depending on the age of the person, the extent and depth of the burn and the patient's cardiovascular status. Smaller amounts of blood should be given to patients with first and second degree burns and somewhat larger quantities employed when third degree burns are present, since more red cells are destroyed or lost in patients with third degree burns. The red cells are not only destroyed initially with heat but are subsequently trapped in the capillaries in the injured area. Because

of a persistent negative nitrogen balance, the presence of infection, the oozing of blood from granulating surfaces and the opening up of new capillaries during healing the patient with a third degree burn requires large amounts of blood initially and often again after the first two to four weeks. It is well to give smaller amounts of morphine, blood and electrolyte solution when treating small individuals or infants and the quantities employed should be governed by the patient's size and the severity of the injury.

LOCAL WOUND THERAPY

Many of the older and more widely employed methods of caring for burned areas have certain disadvantages. Bettman[20] recently reported a 3.1 per cent mortality rate in over 700 patients on whom tannic acid and silver nitrate were used. It was also evident from this study that liver necrosis did not cause death in any of the patients who succumbed; however, it has been shown both clinically [21,22] and experimentally[23] that the use of tannic acid and other chemical eschar producing substances causes local injury to tissues. Thus, when such methods are used it is conceivable that a deep, second degree area might be converted into a third degree burn or that harmful systemic changes may occur. In most instances death due to liver necrosis occurred following a burn when tannic acid jelly was employed or when the patient was put in a bath containing a tannic acid solution.[24,25] However, Salton-stall, Walker, Rhoads and Lee[26] demonstrated by liver function tests that the chemical eschar producing substances usually cause some impairment to liver function, although in many instances it was not severe enough to cause death.

Since more recent studies[27–29] have provided methods which have all the advantages of the chemical eschar methods without their local and systemic ill effects, the use of tannic acid is contraindicated in the treatment of thermal injuries. It has also been emphasized that toxic systemic effects may occur in patients who have had boric acid applied to the burned area or a crystalline sulfonamide compound used as a dusting powder or used in a water soluble ointment base. Since there is little evidence to indicate that the sulfonamides are advantageous when applied locally they are best avoided. The oral administration of the various sulfonamide compounds should not be instituted until an adequate volume of urine is being excreted. Penicillin can be injected safely and should be employed when infection is likely to occur.

In 1942, Allen and Koch[27] described the use of the occlusive or pressure dressing technic. If such dressings are used, vaseline or carbowax is placed over the burned area, followed by layers of sterile gauze dressings, mechanic's waste and an elastic ace bandage or flannel cut on the bias. Although this method had some advantages over the older forms of treatment and has been employed widely during the past few years, it is not entirely satisfactory. First, it is obvious that effective pressure cannot be employed on the head, neck, thorax, or abdomen and thus in these regions the dressings act merely as a sterile covering. When they are applied to the head and neck contamination often occurs due to vomiting or excessive salivation and when they are used on the chest interference with pulmonary ventilation may result. Secondly, application of pressure dressings are often very time-consuming and cumbersome and the patient experiences a certain amount of discomfort when the dressings are changed. Protein, salts and fluid continue to seep into the dressing, not only causing a loss of these constituents but also providing desirable media for bacteria as well as a rather unpleasant odor. In some patients an unexplained fever necessitates removal of the dressing so that the wound can be inspected and the presence or absence of infection determined.

Chase[28] has devised a protein extract from the beef aorta which when applied to the burned area produces an eschar which has no apparent local or systemic

injurious effects. He has employed this technic in several hundred ambulatory patients and more recently Zyla and Weller[30] have used it in more than 400 seriously burned patients and have found it to be quite satisfactory. This protein extract can be applied in ointment form directly to the burned area or it can be put on fine mesh gauze which is then laid over the injured region.

Experience obtained during the war indicated that extensive washing and débridement of the burned area was not necessary. Chase[28] as well as Zyla and Weller[30] have employed a germicidal detergent which is first sprayed over the burned area and followed by a normal saline solution. These workers advocated using the protein extract either in the so-called open method or closed method. In the open method the protein extract is applied to the burned area and the patient is placed on a Bradford frame under a heat tent. Subsequently, if the eschar cracks, more ointment can be applied. In the closed method the ointment is covered by a fine mesh gauze and the region wrapped with a sterile dressing. If infection occurs, the eschar which is produced liquifies. The wound can be frequently inspected when either the open or closed methods are employed without fear of introducing further infection.

More recently, Howes and Ackermann[29] reported a technic for treating the local wound which appears to be sound and especially advantageous in patients with third degree burns. It is efficient, simple, nontoxic and apparently accelerates the separation of the dead tissue resulting from a third degree burn.

NUTRITIONAL AND METABOLIC PROBLEMS OF THE BURNED PATIENT

The nutritional problem of the burned patient has been discussed elsewhere.[31] Briefly, the patient should receive a diet equal to 1.6 times his basal caloric requirement. Twenty per cent of the total caloric intake should be derived from protein. Burned and injured patients should be given a vitamin intake ranging from five to ten times their normal daily requirement.[32] This is especially true of vitamin C and B complex. In patients with mild burns, food can be taken on the day of injury but in those patients with moderate or severe burns it is best to start the oral intake of food on the second or third day. After five to fifteen days the total caloric intake and the amount of protein can be gradually increased as the patient tolerates the food. During the convalescence period the patient by choice drinks large quantities of fluid.[7] Experimental studies[33] and the aforementioned clinical observations indicate that fairly large amounts of water are retained by the body. Thus, after three days the low plasma or serum electrolyte values which are often encountered usually do not indicate a deficiency of these products if adequate shock therapy has been given but result from the retention of abnormal amounts of water. After the first or second day, the intake of large amounts of sodium-containing solutions is best avoided. We have employed a concentrated plasma or albumin solution or a small amount of hypertonic electrolyte solution to promote diuresis and overcome the existing dilution. In extensive third degree burns, it is desirable to increase the oral intake of salt and protein when the necrotic tissue begins to separate and administer blood to prevent or combat anemia and hypoproteinemia.

SKIN GRAFTING AND PREVENTION OF SCARS AND CONTRACTURES

Grafting of third degree burned areas should be carried out as soon as possible. The dermatone method described by Padgett[34] has been found to be satisfactory by most workers. Many of the metabolic changes that occur can be avoided or the duration of these alterations shortened if grafting is carried out promptly. The hazard of infection is also minimized when the unhealed areas are reduced in size. The removal of dead tissue by the application of

pyruvic acid paste as advocated by Connor and Harvey[35,36] or the more recent method of Howes and Ackermann,[29] should contribute greatly in reducing the time required for a seriously burned patient to recover and thus minimize infection, metabolic changes, contractures, etc. Occasionally the early excision and grafting of third degree areas is a helpful way of handling these patients.[37]

SUMMARY

The treatment of patients with thermal burns can be divided into four main categories and the essential points can be outlined as follows.

1. The treatment of shock should be instituted as early as possible and accomplished by the judicious use of whole blood and an electrolyte solution. The relief of pain in such subjects is best accomplished by the intravenous administration of morphine sulphate, grains ⅛ to ⅙.

2. The immediate care of the local wound is best carried out in the following manner: Extensive débridement is not necessary, however, in most patients it is felt that a simple, non-traumatizing irrigation of the area provides some benefit. Following this, either the protein extract advocated by Chase[28] or the ointment advocated by Howes and Ackermann[29] should be applied to the burned area. The systemic administration of penicillin is frequently advantageous for combating infection.

3. The nutritional and metabolic problems can be best summarized as follows: (1) Food is usually omitted (except in those patients with mild burns) for twenty-four to forty-eight hours; (2) a diet containing 1.6 times the patient's basal caloric requirements is then given. Twenty per cent of this diet should consist of a nutritionally adequate protein; (3) after five to fifteen days the diet is gradually increased as it is tolerated so that it will provide adult patients with around 3,000 calories and from 120 to 300 Gm. of protein daily; (4) patients with moderate or severe burns should be given approximately ten times the daily requirements of the water-soluble vitamins and an adequate amount of vitamins A and D for at least two weeks; (5) since water retention occurs, especially between the second and fourteenth day following a burn, and leads to a hemodilution, this is best corrected by restricting the total daily fluid intake to 2,000 to 4,000 cc. and administering a concentrated sterile solution of albumin or plasma intravenously and repeating if necessary. The administration of 250 cc. of a hypertonic electrolyte solution (2 to 5 per cent) can also be administered between the third and twelfth days; (6) during the convalescent period whole blood should be given to correct or preferably to prevent anemia or hypoproteinemia (if the hemoglobin is over 16 Gm. per 100 cc. albumin or plasma may be employed).

4. Since the successful care of such patients is dependent on the early healing of wounds, the removal of sloughing tissue and the grafting of skin should be accomplished at the earliest possible date. If adequate therapy is given as soon as possible, preferably in an attempt to prevent shock, malnutrition, infection and a prolonged convalescence from open wounds instead of overcoming these conditions once they exist, the mortality and morbidity rates show continued improvement.

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ANTIBIOTICS IN THE SURGERY OF TRAUMA*

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THE industrial surgeon is intensely interested in minimizing the incidence of infection in the injuries which he treats. To this end, various bactericidal and bacteriostatic substances have been poured or sprinkled into wounds. During one era, tincture of iodine was used extensively but the tissues rebelled. Later, it was hoped that the sulfonamides would give us a means of rendering wounds sterile without at the same time inhibiting healing. This hope has proved to be futile. The experience of the medical department of the Army[1] and controlled studies by civilian groups[2] showed that the incidence of infection in all types of wounds was not diminished by the local use of the sulfonamide group of drugs. At the present time, if we are to expect any help from drugs in the prevention and treatment of infected wounds, it must come from the field of the antibiotics—antibacterial substances derived from living organisms. For practical purposes this means penicillin and streptomycin, although tyrothricin and bacitracin will be considered.

It is convenient to discuss contaminated wounds under the following headings: (1) Injuries of soft parts, including intra-abdominal and intrathoracic wounds; (2) compound fractures and (3) burns. These may be potentially infected or may show established infection.

INJURIES OF THE SOFT PARTS

When a laceration is treated in the emergency room of the Henry Ford Hospital no penicillin (and of course, no sulfonamide) is placed in the wound. Dependence is placed on the usual surgical procedures, cleansing of the surrounding skin with soap and water, irrigation of the wound with generous amounts of salt solution, excision of devitalized tissue, perfect hemostasis and careful suturing unless the elapsed time indicates that a policy of delayed closure should be followed. When the wound is complicated or extensive and involves, for example, the suturing of tendons and nerves, no antibiotic is used locally but since these patients are usually admitted to the hospital it is common to give systemic penicillin. The usual dose is 12,500 units every three hours by the intramuscular route, although twice or four times this much is frequently administered. The patient will be grateful if the penicillin solution to be injected is matched with an equal quantity of 1 per cent procaine solution. Five days is a reasonable period for such prophylactic treatment.

If one of the serous cavities (peritoneum or thorax) has been entered and contaminated, it is logical to supplement the surgical procedure with the local instillation of 100,000 units of penicillin followed by generous doses of the drug administered by the systemic route.

Three methods have been used in an attempt to avoid the frequent and painful injections which are necessary when penicillin is given intramuscularly. One of these is the continuous intravenous drip. Theoretically, this is ideal because an almost constant blood level can be maintained; however, considerable attention is necessary to keep the constant drip flowing and phlebitis is a frequent complication.

Another method is to suspend the penicillin in a vehicle which inhibits absorption. The most successful mixture is that composed of beeswax and oil (Romansky formula). The available preparations contain 300,000 units per cc., and it has been recommended that this is injected daily in order to provide an adequate blood level. Some observers have found wide vari-

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ability of absorption and excretion of penicillin administered in this manner. For example, Kirby et al.,[3] injected 300,000 units daily into fifty-four patients and found that the assayable levels of penicillin in the blood stream were present for periods varying from four to twenty-eight hours. In 69 per cent of the patients levels were present for no longer than twelve hours and in others the levels were present for sixteen to twenty-eight hours. The subcutaneous route seemed to be preferable to the intramuscular route.

The third alternative route of administration is the oral method. Several commercial preparations are available. The penicillin is mixed with buffers to prevent the deteriorating effect of the gastric juice. The daily oral dose must be approximately five times that of the parenteral dose. Two years ago, Jackson and the author[4] made a study of the absorption of large doses of penicillin administered orally. Fourteen patients were given 600,000 units daily. In eight of these a satisfactory level was demonstrated but half of the patients did not show this level until the fourth day.

From the above comments about the methods of administration it may be concluded that the intermittent intramuscular injection is still the most reliable. It is in the treatment of established infections that penicillin becomes really useful. Even then, it should be remembered that before the days of the sulfonamides and penicillin millions of infections were successfully treated by the fundamental and simple surgical principles which included the employment of rest, heat, incision and drainage. Antibiotic therapy must supplement rather than supplant these measures.

Meleney[5] has recently reported his analysis of 744 patients with surgical infections who were treated with penicillin under the direction of the Committee on Chemotherapy of the National Research Council. The best results were obtained in those patients with furuncles or cellulitis (better than 90 per cent were favorable). In an intermediate position were the infected

Fig. 1. Case 1. Showing extent of third degree burns of thighs (first redressing, two weeks after injury).

soft part wounds and infected operative wounds. Slightly more than 60 per cent of these showed a favorable result. Poor results were obtained in empyema, peritoneal abscess and diffuse peritonitis.

Streptomycin may be tried if cultures show gram-negative organisms or if sensitivity tests indicate that the organism is resistant to penicillin but not to streptomycin. It should constantly be borne in mind that in chronic infections an organism may become penicillin-fast after having been originally sensitive. The dose of streptomycin is 1 to 4 Gm. daily, given intramuscularly in divided doses every three hours.

Tetanus does not respond to the antibiotics. Altemeier[6] reported that no beneficial effect of penicillin on the course of established generalized tetanus was observed in a clinical study of sixteen patients. This is disappointing in view of the fact that penicillin inhibits the tetanus bacillus in the test tube. The difficulty probably lies in the fact that penicillin has no effect on the toxin which is the lethal material. The author recently observed tetanus develop in a severely burned patient who was receiving large doses of penicillin. Evidently, there is no certain prophylactic effect. On the other hand, a number of reports indicate that penicillin is a valuable

FIG. 2.

FIG. 3.

FIG. 2. Case 11. Condition of legs on admission. Note ineffectual attempts at skin grafting.
FIG. 3. Case 11. Posterior aspect of legs.

adjunct to orthodox surgery in the treatment of gas gangrene.

COMPOUND FRACTURES

As a prophylactic measure against infection in compound fractures, all patients admitted to the Henry Ford Hospital with this injury are given intramuscular penicillin for at least two weeks. An average patient would receive 50,000 units every three hours for the first week and half that dose for the second week. No drug is used locally.

Penicillin therapy is of value if the compound fracture becomes infected and osteomyelitis develops; however, it is in hematogenous osteomyelitis that the drug has given such miraculous results. Altemeier[7] reported on thirty-four patients of whom twenty had positive blood cultures. Seventeen required no surgical intervention while twelve had incision and drainage of soft tissue abscesses and five had incision and drainage plus osteotomy. No patient required sequestrectomy. There was no death in the series.

With chronic cases of osteomyelitis the results are less satisfying. Of the first nine patients treated at the Henry Ford Hospital only one showed slight improvement. At the present time the method of Coleman and his associates[8] is being evaluated. These authors treated fifty-two bone defects by sequestrectomy followed by packing with bone chips. Penicillin was used locally and systemically. Closure was obtained in 92 per cent of the lesions.

BURNS

It is probably unnecessary to give penicillin in the acute phase of a burn. Fever and leukocytosis are constant features of this stage and it is difficult to tell if infection is developing. If there is very high fever, chills, positive blood culture or other good evidence of infection antibiotic treat-

ment should be begun. Penicillin also appears to be especially valuable during the stage of skin grafting.

Case I. A. McD., a boy, aged eighteen, was admitted on July 9, 1943, following severe flame burns of both thighs, the abdomen, chest and right arm. (Fig. 1.) He was dressed with petrolatum gauze under pressure. After the third degree areas had sloughed, dermatome grafting was begun on August 4th. There was a fairly satisfactory take of the first grafts but there was less and less success with the operations which followed. After eleven stages of grafting there were many granulating areas, including most of the donor areas which had become infected. Culture of the pus yielded Staphylococcus aureus, Staphylococcus albus and the non-hemolytic streptococcus. Hemoglobin, plasma proteins and vitamin C levels were normal. Following the next stage of Reverdin grafting on December 6th, he was given 100,000 units of intramuscular penicillin daily and the grafts were kept moist with saline solution which contained 100 units of penicillin per cc. The take of these grafts was about 80 per cent, as compared with 5 per cent for the preceding operation. After four more stages of Reverdin grafting he was discharged on March 22nd. Penicillin was almost certainly responsible for the success of the later skin grafting procedures. He received 5,000,000 units intramuscularly and 1,500,000 by local application.

The following case illustrates the possibilities when one is confronted with the problem of a large, neglected burn.

Case II. G. Z., aged seventeen, was burned on October 20, 1943, when his trousers caught fire while he was handling turpentine. He was admitted to another hospital and tannic acid was applied. On December 15th, and again on February 15, 1944, a few Reverdin grafts were applied. These procedures did little toward covering the large granulating areas. He was transferred to the Henry Ford Hospital on March 23, 1944. The legs were bathed in pus from which was cultured the Staphylococcus aureus, non-hemolytic streptococcus and Bacillus proteus. The boy was malnourished; there were pressure sores over the sacrum and the anterior superior spines. (Figs. 2 and 3.) He was given penicillin and transfusions and skin grafting was begun in a week. During the next three months he had ten skin grafting operations. Five of these were of the dermatome variety and five were Reverdin. At the end of this time he was covered with epithelium but had a fibrous ankylosis of the left knee. (Fig. 4.) He received 12,500,000 units of penicillin by the intramuscular route.

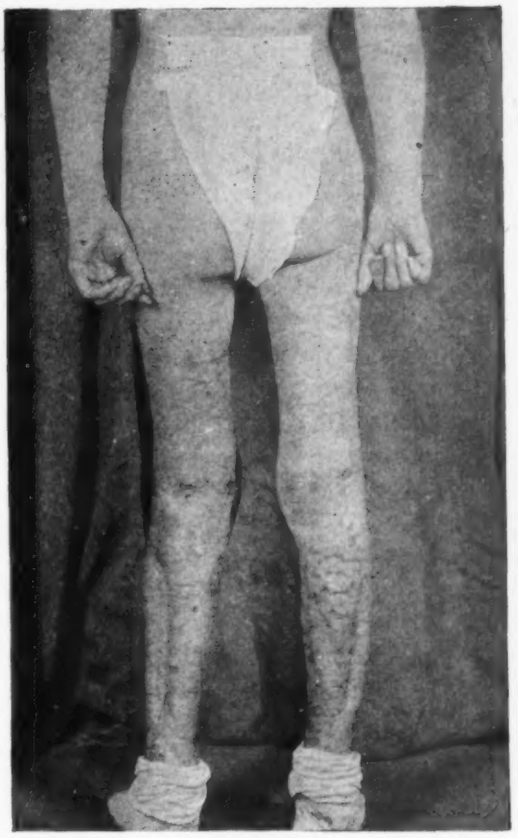

Fig. 4. Case II. Condition of legs after skin grafting. The depressed scars were subsequently removed.

Theoretically, streptomycin should be of value when there is pyocyaneous infection of the granulating burned surfaces.

TYROTHRICIN AND BACITRACIN

The author has had little experience with tyrothricin and none with bacitracin. Tyrothricin is the product obtained from Bacillus brevis (Dubos) and contains 15 to 20 per cent gramicidin and 40 to 60 per cent tyrocidin. It is effective *in vitro* against the common gram-positive cocci. It is suitable only for topical application. Kozoll et al.,[9] used tyrothricin as a wet dressing in the treatment of seventy-seven patients

with surgical infections, the majority of whom had failed to respond to previous methods of treatment. Twenty cc. of the 2.5 per cent alcoholic solution were added to a liter of distilled water, thus making a solution which contained 0.5 mg. per cc. It was felt that 65 per cent of the patients showed excellent clinical results. They concluded that "Tyrothricin is recommended as a nontoxic, noninjurious antibiotic agent for local use in the treatment of surgical infections, if these meet the following criteria: (a) the wound is open, (b) there is adequate blood supply and (c) the predominant organisms are streptococci or staphylococci or both."

Meleney and Johnson[10] discovered an aerobic gram-positive spore-forming bacillus which produced an antibiotic substance. Because the organism was found in the débrided tissue from the compound fracture in a little girl named Margaret Tracey, the new substance has been named bacitracin. These workers used the material locally in the treatment of one hundred patients with surgical infections, including furuncles, abscesses, infected operative wounds, chronic osteomyelitis and chronic ulcers. It was thought that there was a favorable response in 88 per cent of the patients. Of special interest was the fact that thirty of the strains of cocci encountered were resistant to penicillin but susceptible to bacitracin. This would indicate that the new antibiotic may be of considerable clinical importance, when and if it becomes generally available.

SUMMARY

1. The antibiotics have not obviated the need for orthodox surgical procedures in the prophylaxis and treatment of infected wounds.

2. As valuable adjuvants they have controlled the infection in some patients, and in others they have made possible certain surgical procedures hitherto impossible.

3. Rational treatment demands a full bacteriologic diagnosis of the inhabitants of the wound. This diagnosis must include information about the vulnerability of the organism or organisms to the available antibiotics.

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AMPUTATION LESSONS FROM THE WAR

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THE civilian or military amputee is faced by a triple threat to his scheme of life by the physical and vocational disability caused by the loss of his limb, by his emotional reaction to his disability and by the attitude of the public toward his defect. His adjustment, therefore, is a challenge to the surgeon's clinical judgment, the limb maker's technical skill and the social conscience of the public. The lack of coordinated effort on the part of these three groups in the past has been responsible for the limited and unsatisfactory adjustments made by many amputees.

The evolution of military care for the amputees in the wars of America was marked in the early days by the limited state of medical knowledge and administrative negligence. The 50,000 men who lost their limbs in the Civil War because of gunshot wounds and hospital gangrene did not have the advantage of modern antibiotics. Nor was the furnishing of artificial limbs considered a proper function of the military organization. For the 4,403 who lost their limbs in World War I only a limited service was provided within the framework of the hospital. The major service was not rendered until discharge from the hospital. It remained for World War II to introduce the concept of rehabilitation in the treatment of the amputee. This was a three dimensional type of service provided at special hospital centers which prepared the amputee for return to society immediately after discharge from the hospital. It contemplated a series of coordinated activities beginning at the time he was hurt and continuing until he was restored to physical and social and in many cases to his previous vocational status.

PSYCHOLOGICAL PREPARATION

The first step in this plan was that of psychological preparation. The emotional reaction to the loss of a limb varied to a great extent. There were those for whom the injury was a ticket to stateside. For them the war was over. On the other hand, there were many beset with doubts and fears and qualms showing through the thin veneer of bravado. How will my family take it? Will my girl turn me down? Will I ever walk? Will I be able to work? To resolve these anxieties was the responsibility of the medical officer. By reassurance, by demonstration of successful amputees. by the day to day contact with shipmates and buddies with the same type of disabilities, these apprehensions were allayed. But the process and rationale of rehabilitation with its successive steps had to be understood if complete cooperation was to be obtained. Many future problems could be anticipated and eliminated by preliminary briefing, by individual interviews or class discussions. Weekly walking clubs or discussion groups ironed out uncertainties and complaints. The amputee had to be a partner in this enterprise of which he was the beneficiary.

SURGERY

The second step in the rehabilitation program was the actual surgery of amputations. While the surgical principles and methods of amputation have been more or less standardized over the years, the war experience was a valuable laboratory for the confirmation of those ideas that have withstood the test of time. At the same time it provided an opportunity for the introduction of new methods and

FIG. 1. FIG. 2.
FIG. 1. Stump of Syme's amputation.
FIG. 2. Below knee amputation.

technics which supplemented the standard procedures.

Conservatism was the keynote. Of more than a million casualties only 18,000 suffered amputation. This was a tribute to the planning of the medical departments. Despite long distances and unfamiliar terrain and in many cases limited supplies the work was carried out with great efficiency. Planning included not only hospital organization and evacuation facilities but also directives for guidance of the surgeon in forward areas concerning indications for amputation, technic, postoperative care and definitive treatment.

Indications. Practically all the allied military medical services agreed concerning the indications for amputation. The primary indication was that of loss of blood supply. The second was that of fulminating infection especially gas bacillus infection. The third and less urgent was the instance of severe and irremediable mutilation.

Open Amputations. All the allied medical services also agreed on the adoption of the open amputation as the technic of choice in combat areas. However, there was considerable variation in the actual measures employed. The advocates of the classic guillotine amputation adhered rigidly to their formula. But time and again the operation was frequently performed at the site of election instead of the most distal point of viable tissue with consequent loss of valuable bone length following revision of the stump. In the short below the knee amputations this frequently resulted in the loss of the valuable knee mechanism. Furthermore convalescence was unusually

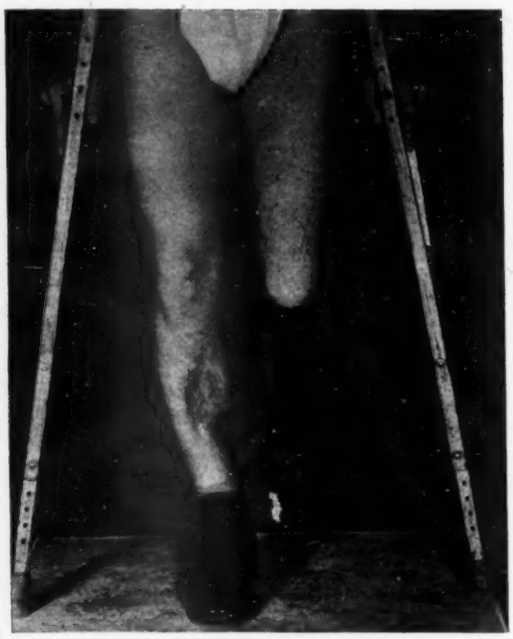

FIG. 3. Stokes-Gritti amputation without prosthesis.

FIG. 4. Above the knee amputation.

prolonged because of the large open area that had to be covered by gradual contraction of the skin.

Because of these complications the true guillotine amputation was reserved for cases of malignant infection only. In other injuries the open amputations were modified as follows: A circular incision was made through the skin and fascia at the most distal point of viable tissue. The flap was turned back as a complete cuff for about three inches. With a large amputation knife the remaining muscles were cut through as in the true guillotine amputation. The periosteum was incised at the level avoiding the stripping of the bone. The large vessels were doubly ligated with chromic gut, the nerves sharply divided without manipulation or injection and allowed to lie free in the intermuscular planes. The cuff of skin and fascia was then allowed to cover the open end of the stump and skin traction with moleskin strips was applied. By this procedure the healing period was shortened from six to eight weeks to two to three weeks. The skin closed rapidly so that skin grafting or wide excision of the scar at the time of revision was unnecessary.

The aim of the open amputation is to save life and prevent the complication of flap disruption and infection where primary flaps are employed. Certainly the latter technic is contraindicated in a combat zone. In industrial accidents where unclean conditions obtain the same principles hold true.

Definitive Treatment. However the aim of the final operation whether by plastic repair of the stump, revision or reamputation, is to obtain the best possible stump and one of optimum length, or a shape that allows it to be fitted properly with an artificial limb and a terminal scar so placed that it is away from the pressure of the artificial limb bucket. The skin should be supple and not adherent to the bone.

The experience of the military services in all the countries agreed on the employment of a limited number of standard

Fig. 5. Syme's prosthesis.

procedures for the final and definitive operations. While it has been the custom to choose from as many as thirty operations and more for the lower extremity according to one's personal experience and whim, the military experience has reduced this number to four basic procedures. These are the Syme's amputation at the ankle (Fig. 1), the below the knee amputation (Fig. 2), the Stokes-Gritti amputation (Fig. 3) and the above the knee amputation. (Fig. 4.) While modifications of these standard procedures are indicated under special conditions, the four basic measures should meet the needs of the average case.

Syme's Amputation. This type of amputation should be used for any injury to the foot in which the loss of tissue is proximal to the tarsometatarsal joints. The loss of this joint makes weight-bearing difficult and attempts to save that portion of the foot results in unsatisfactory amputations which are disabling, time consuming and frequently requires reamputation with resulting economic disability. Syme's amputation provides an adequate and desirable end-bearing stump. Direct weight is borne on the skin flap made from the original heel, long accustomed to weight bearing.

In this amputation the tibia and fibula

Fig. 6. Stokes-Gritti prosthesis.

are transected at a point about ¼ inch proximal to the articular surface of the tibia. The os calcis is removed subperiosteally preserving the skin of the heel which is then used to cover the cut ends of the tibia and fibula.

In the Syme's and Stokes-Gritti amputations the resultant stump is end-bearing. The lack of popularity and even opposition to these procedures in the past has been encouraged by some limb makers who found it difficult to construct satisfactory prosthesis for these stumps. This is a weasel attitude particularly when we review the excellent prostheses made in service amputation centers by recently trained personnel. In this regard the Canadians were a large factor in stimulating interest and enthusiasm for these methods in view of their long successful experiences.

Below the Knee Amputation. In any amputation above the ankle, the optimum site is 5 to 6 inches below the knee. At this level the optimum conditions of leverage and support are available. Longer stumps can be fitted with boot or "Muley" legs but the stumps soon break down from excessive assymetrical pressure. Stumps of 2 to 3 inches below the knee can also be effectively utilized especially if most of the muscles clothing the tibia and fibula are removed, leaving a stump essentially of skin and bones.

In the standard operation below the knee the patient is placed on his face. Slightly unequal flaps are made with the anterior flap somewhat longer. The flaps are reflected and held in place with a single suture to avoid handling and retraction. The muscles are cut through somewhat obliquely in order to secure a graduated conical stump with a large knife. The interspace between the fibula and tibia is also cut through with the same knife. The tibia is incised in a circular manner and the periosteum stripped distally and sawed through. The fibula is treated in the same manner but is cut 1 inch shorter using a Gigli saw. The anterior crest of the tibia is bevelled. The nerves are carefully isolated, cut sharply and allowed to fall back into their intermuscular spaces without unnecessary traction, or manipulation, injection or other handling. The large vessels are seized, clamped and tied and the tourniquet removed. The remaining bleeding is controlled by pressure and hot laps or by electrocoagulation if available. The skin flaps are closed with interrupted sutures and drains inserted for forty-eight hours. Drains were found to be necessary because of frequent hemorrhage and hematoma formation.

The resulting stump is satisfactory for the routine pursuits of life. Weight is not borne on the end of the stump but on three pressure bearing areas, the internal condyle of the tibia, the tibial tubercle and the head of the fibula. The fibula was rarely removed except in exceedingly short stumps. If the artificial limb is fitted properly, these pressure areas will carry the weight evenly distributed. When the weight is improperly distributed excessive weight falls upon one of these points causing skin irritation, pressure sores and inability to wear the prosthesis. Accuracy of limb fit avoids this complication. Where excessive weight is required the

Fig. 7. Cineplastic prosthesis for forearm.

limb maker can so distribute the weight bearing strain to other parts of the thigh and ischium as to relieve the amputee from pain and discomfort.

These weight bearing points must, therefore, be free from scar or defect to permit them to carry out their new physiological demands. In above the knee the weight is transferred to the ischium but depending on the length and shape of the stump some of the weight is carried on the circumference of the thigh stump. In very short below knee stumps the weight is shared between the weight bearing points previously mentioned and the thigh lacer or corset. In exceptional cases some of the weight in these short below knee stumps can even be borne on the ischium through the medium of a blocked roll of leather on the upper end of the thigh lacer.

It is important to remember these four basic types of amputation. Remember that they are the most practical from a functional and prosthetic point of view. Modifications of these procedures may be indicated for pathological reasons but not for prosthetic purposes.

Upper Extremity. In the upper extremity many attempts have been made to restore the prehensile function of the hand by means of surgical methods. The cineplastic operation is in this category. By means of skin canals in muscle groups of the forearm or upper arm prosthetic devices can be operated in a natural and automatic fashion. In other instances the forearm can be split into two finger elements of radius and ulna and their approximations provide prehensile power. For the bilateral blind amputee the retention of tactile sensation is not only desirable but indispensable. However, these methods as well as the utilization of the wrist movement in mid-carpal amputations are special methods to be utilized to meet the needs of specific cases. The basic amputations are the above wrist, below elbow and above elbow amputations. Disarticulations are to be avoided for prosthetic reasons.

AFTER-CARE OF STUMP

Contractures. The third step in the rehabilitation program of the amputee was concerned with the after-care of the stump. This matter has always been neglected or overlooked in civilian life and bears considerable and thoughtful attention. Many of the difficulties in limb adjustment can be traced to stumps that are contracted, weak or improperly shrunk. The limb manufacturer is frequently criticized for his product when the fault owed its origin to faulty habits begun soon after operation. These contractures of the hip and knee can be prevented by proper posture in bed, by the avoidance of comfortable pillows under the stump and by exercises designed to maintain the full length of the stump and its adjacent joint. When the contracture is severe it is a mistake to fit that patient

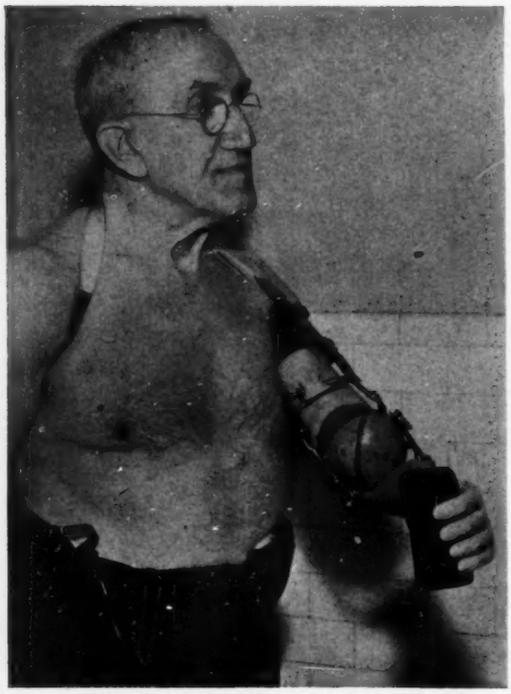

FIG. 8. Cineplastic prosthesis for above the elbow.

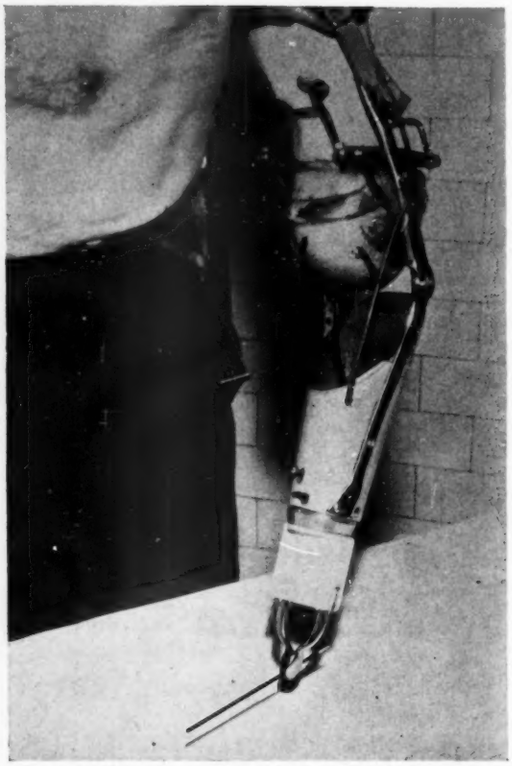

FIG. 9. Cineplastic prosthesis with interchangeable utility hook.

with a limb until the contracture is corrected by manipulation, gradual traction or other means.

Shrinking. Shrinking of the stump has always been regarded as an unnecessary and unpleasant task by the amputee. He knows that the stump will shrink with time and hence cannot understand why he must pay much attention to this chore. But shrinking cannot be left to time or indiscriminate attention. Only by systematic care can the proper shape of the stump be achieved and the shrinking process be expedited so that the permanent limb can be worn. Furthermore symmetrical development of the skin resistance to pressure prepares the amputee for comfortable as compared to uncomfortable limb wearing. Irregular attention to shrinking also invites intermittent changes in volume of the stump which postpones the application of the permanent limb and invites circulatory and neural trouble.

Exercise. There is a third phase of stump care that has also been overlooked but one which received considerable attention in military practice. This was concerned with the exercise of the stump. In the thigh stump for example it was frequently found that a considerable imbalance resulted favoring excessive activity of the abductors over the adductors. By the exercise of the adductors and the extensors the tendency to an abduction gait was either prevented or corrected. This permitted the amputee to walk in the proper manner with his muscles so balanced as to maintain good mechanical alignment. While this exercise program may be optional for some of the patients it is indispensable for the patient with a bilateral amputation above knee. With poor abdominal muscles he is unable to balance himself and thus becomes discouraged early in his training period. These exercises are undertaken not when the prosthesis is secured but they are initiated soon after the operation. For the individual with severe amputations, the advantage of general muscle training even for the muscles not directly employed in operating the prosthesis is obvious.

PROSTHESIS

We have discussed the general problems of the amputee, how his amputation produces physical, emotional and social by-products which may overwhelm him in his efforts to make a livelihood. Yet all these problems can easily be solved by means of a properly constructed and fitted prosthesis. The artificial limb restores his functional defect by giving him another source of power to ambulate. The prosthetic device makes him look and feel whole and thus restores confidence in himself as a normal person. Finally, by the restoration of his physical appearance he is restored to social normality.

And what were the contributions of the war to the advancement of prostheses? We were led to expect miracles from the inventors' pipe dreams. After all we had performed a miracle of production. We had invented an atomic bomb, we had developed a thousand and one engineering improvements which gave us the measure of superiority against two of the greatest fighting dynasties in history. Could not this same engineering genius devise new miracles in the form of prosthetic devices? Alas neither private industry nor government mobilized engineering skills have found the Rosetta stone to unlock the mystery of human movement. Some minor improvements are in the course of development; some ideas like the suction socket have been rediscovered by the Germans after an American first described it more than eighty years ago. In the main there have been no major improvements. Plastics are still in the first stage. Cosmetic gloves show promise. The basic material ideas employed in artificial limbs today are those that have been in use for more than fifty years. This is not to be construed that they are not satisfactory for they have given comfort and utility to millions of users.

But there are other contributions of the war to the problem of prosthesis that are just as important as improved materials or special devices. This has to do with organization of prosthetic services. At the amputation centers the prosthetic service was concerned with three phases, the selection of the prosthesis, its fabrication and the fitting. The selection of a prosthetic device was the proper responsibility of the medical officer who was trained not only as an amputation surgeon but also as a limb fitting surgeon. This is a new departure in this country for only in England at the Ministry of Pensions center at Roehampton does this obtain. This means that as a result of war experience the Army and Navy trained surgeons to be able to inspect a limb and critically evaluate it. Thus he was in a position to certify as to its value in the given case. This is a far cry from the average surgeon who must accept the limb makers judgment unless he has had the special opportunity to familiarize himself with problems of prosthesis.

Selection of prosthesis is of especial importance in the upper extremity. For the lower extremity prosthesis is pretty well standardized. In the upper extremity, however, the prosthesis is selected not just to fit the patient's stump, but to fit his whole personality and total industrial and social needs. There is no one miracle arm that will answer all these demands. An interchangeable dress and work arm will have to meet the needs of the average person in industry. But whether it is to be operated by standard lanyards and shoulder controls or by cineplastic controls will always be the personal decision of the patient himself.

The establishment of facilities for the fabrication of the prosthesis in the hospital amputation center was a distinct innovation. Not only were standard materials such as wood fiber and metal employed but experimental research was carried on with plastics. The advantage of this program of fabrication and fitting for the patient was obvious. Instead of bringing the patient to the limb fitter the latter was brought to him. The fitting of artificial limbs is an art requiring great skill and experience yet the

military limb making and fitting personnel gradually developed these skills after many false starts.

TRAINING

The fifth step in the rehabilitation program of the amputee was the training program instituted for the adjustment of the amputee to his limb. This, too, was an innovation not only for the military establishments but for the whole limb industry. It filled a serious gap in the total adjustment of the amputee that had been given too little attention in the past. One of the shortcomings of private limb industry was their inability to furnish proper training in the use of the limb. While a certain number of amputees adjusted themselves quickly to their limb and became satisfactory walkers or users of arm prosthesis, the majority made only a mediocre adjustment to their limb. Another group found it impossible to wear their limbs at all. By systematic training the middle group became excellent walkers while even those with above knee bilaterals and other serious handicaps became satisfactory walkers.

The training program required trained personnel and systematic activities as a result of which the patient learned balance, proper gait, and control and ability to make the most out of his limb. After basic training was completed training and conditioning were continued to include all the routine pursuits of life, dancing, athletic sports, roller skating, etc. Thus the amputee was prepared to take his place at work in the community and in the family without asking any favors.

SUMMARY

This then was the contribution of the war toward the advance of knowledge concerning amputations that only by an integrated plan of action can the amputee be properly served. Such a program includes the five points of psychological preparation, surgery, after-care of stump, prothesis and training. The war experience points a lesson to those of us who in civilian life are responsible for the rehabilitation of the physically handicapped. In four years that produced 18,000 military amputees 120,000 civilians lost their limbs by accidental injuries and disease. For them no comprehensive program comparable to the military program exists; but if they are to be reassimilated into American life, they must be provided with those facilities. It is the hope of the Office of Vocational Rehabilitation that civilian centers will be established that will follow the satisfactory trend of military amputation centers.

FREE TENDON GRAFTS IN SECONDARY FLEXOR TENDON REPAIR*

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A COMMON injury requiring the use of a free graft in secondary repair is the severed deep flexor tendon in the distal palm or proximal phalanx. The tendon is disrupted in the region of the proximal annular ligament where a primary suture frequently fails, unless it is done with the most exacting technic under favorable conditions. Severed tendons complicated by fractures of the metacarpals or phalanges, as seen in crush and missile injuries, are repaired following union of the fractures, resurfacing if necessary and joint mobilization. In clean wounds, even though tendon repair is delayed, severed palmar and digital nerves can be sutured at the time of primary wound closure.

This discussion deals only with those patients that come to secondary repair because of a loss of interphalangeal joint flexion. Our problem is the restoration of a strong, freely gliding tendon of sufficient amplitude to permit the finger to be flexed in coordination with the other fingers through a useful functional range. We resort to a free graft or transfer, because of tendon retraction and the desirability of having an intact tendon within the finger. In general, one badly injured finger is not worth reconstruction. When the hand injury is extensive, however, our aim should be to restore any part which may contribute to the end functional result. For example, a free graft may not fully flex a finger but it may stabilize it to such a degree that a good pinch with the thumb is possible. For the best results in free flexor tendon grafting the palm and fingers must be covered by skin free of scar, the joints must be mobile and good sensation must be present.

If the sublimis tendon is intact, producing good proximal interphalangeal joint flexion, a free graft is not indicated. It is better to fuse or tenodese the distal interphalangeal joint at approximately 30 degrees of flexion. In primary repair, when

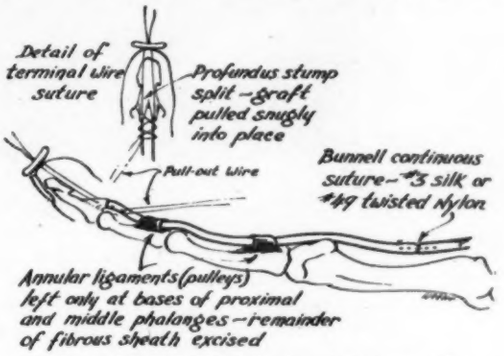
Detail of terminal wire suture
Profundus stump split – graft pulled snugly into place
Pull-out wire
Bunnell continuous suture – #3 silk or #49 twisted Nylon
Annular ligaments (pulleys) left only at bases of proximal and middle phalanges – remainder of fibrous sheath excised

FIG. 1. Sketch showing free tendon graft.

the profundus tendon is severed distal to the sublimis bifurcation in the region of the middle phalanx, an end-to-end approximation of the tendon may be possible. The suture should be made as near the profundus insertion as possible even if it means sacrificing a portion of the distal stump.

OPERATIVE PRINCIPLES AND TECHNIC

The fingers and palm are opened by lateral and curved incisions under tourniquet hemostasis. (Fig. 3.) If the sublimis tendon is to be used as a free graft, it can be withdrawn through a transverse incision at the wrist. Small caliber tendon grafts are preferable, for they are readily vascularized and are not constricted by the rigid annular ligaments. The palmaris longus or the toe extensors make excellent grafts and are easily obtained. They will hypertrophy if necessary to meet the functional demand placed upon them. Free grafts undergo swelling during the early postoperative

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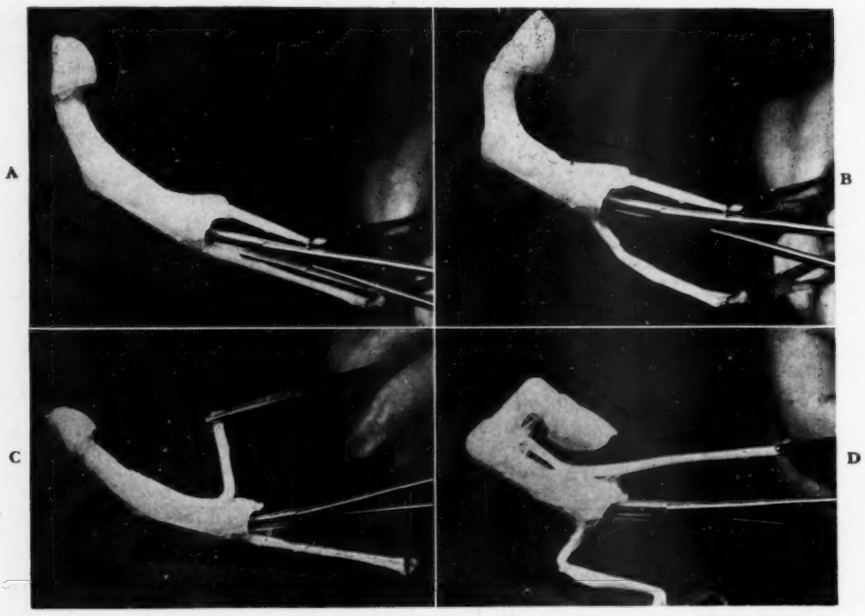


FIG. 2. A and B, an intact finger freshly amputated showing the extent of the fibrous, flexor tendon sheath. Traction on extensor and deep flexor tendon produces only limited extension and flexion. The tendon has remained inactive within the sheath for several months following a wrist injury and the tendon has become adherent. C and D, excision of the sheath excepting two pulleys permits improved extension and full flexion. A similar condition exists when a free graft is placed within a fibrous sheath. By eliminating all but two pulleys, adherence of the graft to a rigid structure is partially eliminated.

phase and pressure necrosis or adhesion of the graft may result if there is not ample space within the annular ligaments. If the graft lies on a cicatricial bed or exposed bone, paratenon from over the triceps tendon should be interposed to form a gliding mechanism or the graft can be transplanted with its paratenon intact.

One of the most important features in preparing the finger for a free tendon graft is a complete excision of the fibrous tendon sheath, excepting enough of the pertinent pulleys (annular ligaments) to prevent bowstringing. (Figs. 1 and 2.) They are located near the bases of the proximal and middle phalanges. If they are destroyed or collapsed, only the proximal one should be reconstructed at the time of tendon grafting. The flexor tendon remnants are removed, leaving only the stump of the profundus tendon at its insertion. (Fig. 1.) Soft tissue and not the tendon sheath is a prime requisite for good function of free tendon grafts within fingers.

When a retracted tendon is prolonged with a free graft, the length of the graft must be carefully determined to insure coordinated muscle balance and function within a useful range. A graft will shrink somewhat but a retracted muscle may compensate by an increase of amplitude. A graft is approximately the correct length when it holds the finger in a neutral position with a flexor tone equal to the normal finger. Correct tendon graft length is facilitated by placing a strong proximal suture first; then, with the graft threaded through the pulleys the distal suture can be placed at the proper tension.

A profundus tendon may retract less than a sublimis tendon when severed, if it remains in continuity with an intact lumbrical muscle or if it is checked by an adjacent profundus tendon. Before any severed tendon is prolonged with a free graft, its amplitude should be determined by traction, for it is futile to prolong a severely contracted flexor muscle with a

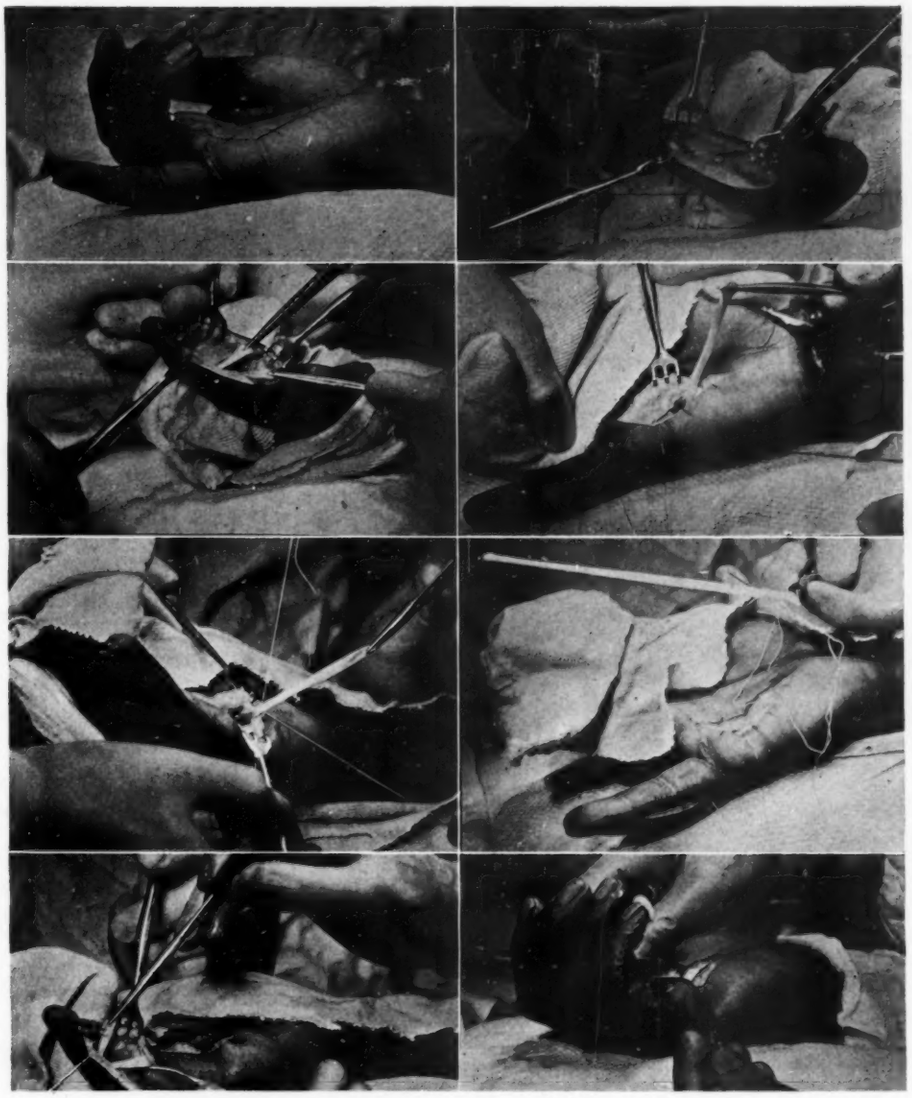


Fig. 3. A to H, steps illustrating the use of a free graft to repair a severed profundus tendon. Note the site of injury and the testing position of the intact index, middle and ring fingers. The injured portion of the tendon is discarded and a palmaris longus graft is sutured to the profundus at the lumberical level, threaded through two pulleys and united to the profundus stump at the terminal phalanx with steel wire. With the graft in place, the finger assumes the same degree of flexion as the intact ring and middle fingers. Between two and three months of persistent exercise beginning three weeks postoperatively are required to gain function.

graft and expect sufficient amplitude to develop for full finger flexion. In fingers, either the profundus or sublimis can be used for power. The profundi are the stronger and are preferable but only that of the index finger has full independent action. The sublimi are all independent. A free graft of either or of all the three common profundus tendons must therefore be carefully coordinated if the middle, ring and little fingers are to flex and extend in unison. In some few patients it may be desirable to utilize a sublimis for power if its amplitude is greater. The sublimis of the little finger is usually too small for use, either as a graft or for power. Whenever a profundus tendon is prolonged with a graft, additional motor power can be gained by suturing to it the associated sublimis tendon at the wrist.

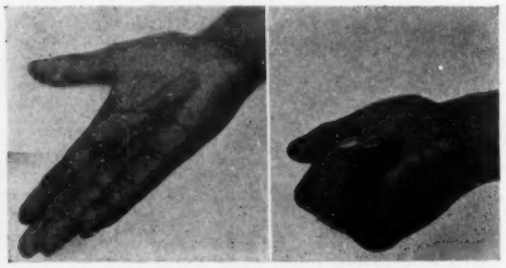


Fig. 3.1 and J, range of motion gained during the first six weeks of active exercise. About 15 degrees of flexion have been gained at the distal interphalangeal joint. A complete range should result by the end of six months.

Fig. 4. Method of exercising finger to gain flexion of interphalangeal joints by first holding the metacarpophalangeal joint rigid, thus transmitting the pull to the proximal interphalangeal joint; then by holding both metacarpophalangeal and proximal interphalangeal joints, the pull can be directed toward the distal interphalangeal joint.

A sturdy, proximal end-to-end suture and firm fixation of the tendon graft at the insertion is imperative. The Bunnell continuous suture with untreated silk (No. 3) or twisted Nylon (No. 49) is preferred for the proximal tendon juncture and his stainless steel wire (No. 34) technic at the insertion. (Figs. 1 and 3.) If the profundus is used the graft should be sutured at the level of the lumbrical origin in the soft tissue of the palm—the tendon juncture may be covered by this muscle. Full finger flexion cannot be gained, if in the presence of an intact lumbrical, the graft is made too long or if the lumbrical is contracted. The lumbrical muscle acts both as a flexor of the metacarpophalangeal joint and as an extensor of the interphalangeal joints; its base (origin) is the shifting profundus tendon. Actually, the profundus muscle has a dual insertion through the tendon and the lumbrical. Its direct pull is transmitted to the terminal phalanx but at

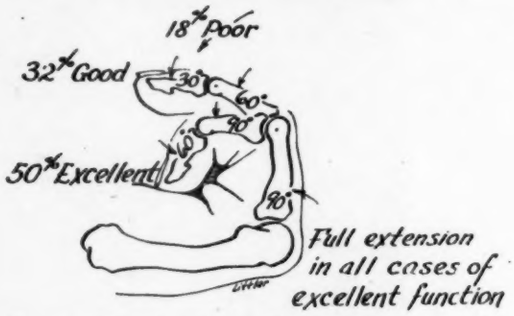
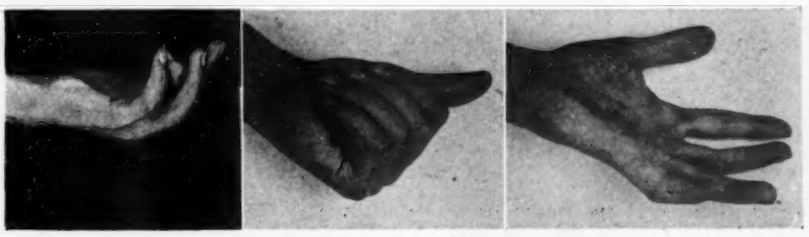


Fig. 5. Criterion for results as expressed in this paper.

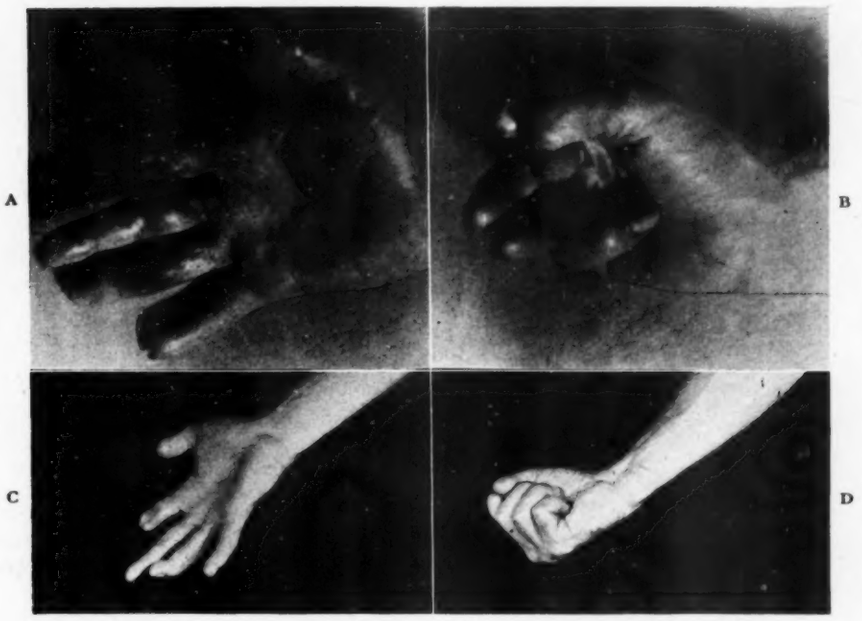
all times excursion of the tendon is acted on by the lumbrical; as the finger is extended the lumbrical relaxes the interhalangeal joints by advancing the profundus tendon. In finger flexion the lumbrical through its extensor action on the interphalangeal joints prevents acute flexion of the distal interphalangeal joint. Kaplan[3] has aptly termed the lumbrical as the moderator between the long extensor and flexor tendons.

Fowler has shown that an intact ring finger sublimis tendon can be detached at the proximal interphalangeal joint, withdrawn through a palmar incision and transferred to the little finger to replace a severed profundus tendon. The ring sublimis tendon can also be transferred to the terminal phalanx of the thumb, if a damaged flexor pollicis longus tendon is not amenable to repair either by suture or graft or especially if the muscle has been damaged. This transfer eliminates the use of a free graft and provides an intact tendon from muscle to insertion, which is free of any suture. However, the transferred tendon acts as a free graft, in that it must also regain a blood supply for its survival. Tendon grafts do poorly in anesthetic fingers and should not be placed until sensation has been restored through nerve suture.



A B C

Fig. 6. Case 1. A to C, laceration of sublimus and profundus tendons of all fingers at distal palmar crease. Primary suture with black silk resulting in a useless hand. Results following one-stage removal of all sublimi and prolongation of the four profundi with free sublimis grafts.



A B C D

Fig. 7. Case 2. A to D, crushing injury of hand with partial loss of digits and complete loss of middle and ring finger interphalangeal joint flexion. Ring finger resurfaced with pedicle flap. Free tendon grafts placed in middle and ring fingers. Pulley constructed at middle phalanx of ring finger.

Careful hemostasis and a pressure dressing will prevent the formation of a hematoma in the palm. Stainless steel wire (No. 36) is used for skin closure. Relaxation of the tendon is gained by immobilizing the hand in a dorsal plaster splint with the wrist, metacarpophalangeal and proximal interphalangeal joints each flexed at approximately 45 degrees. The dressing is not disturbed for three weeks and uninterrupted elevation of the hand is important for at least forty-eight hours following operation.

Good primary healing with a minimum of cicatrix is gained through immobilization. Early motion has no place in free tendon grafting, for not until three weeks have passed are the tendon junctures united. An untraumatized tendon will not adhere firmly to surrounding soft tissue if left undisturbed for this period. During the early postoperative phase, when the graft is swollen, softened and avascular, motion promotes the formation of scar and adhesions. The cicatricial index and reaction to injury varies in patients and has some influence on the final functional result in tendon surgery.

At the end of three weeks the skin sutures are removed and the pull-out wire

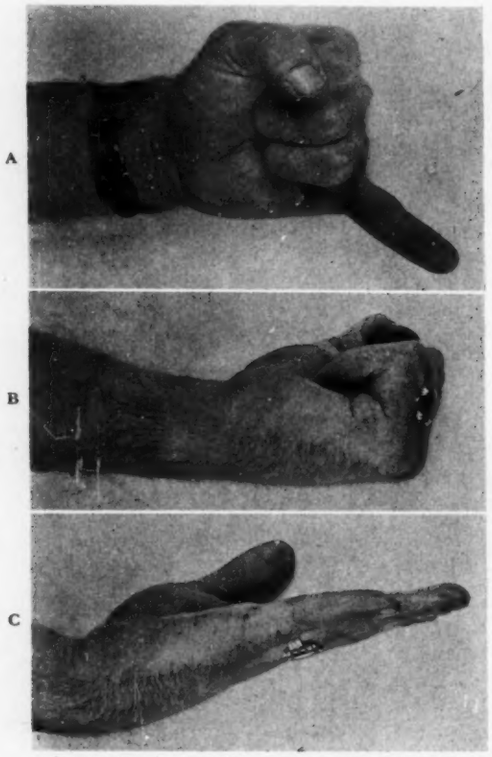


Fig. 8. Case III. F. F. A to C, flexor tendon laceration. Function gained two months after free tendon graft.

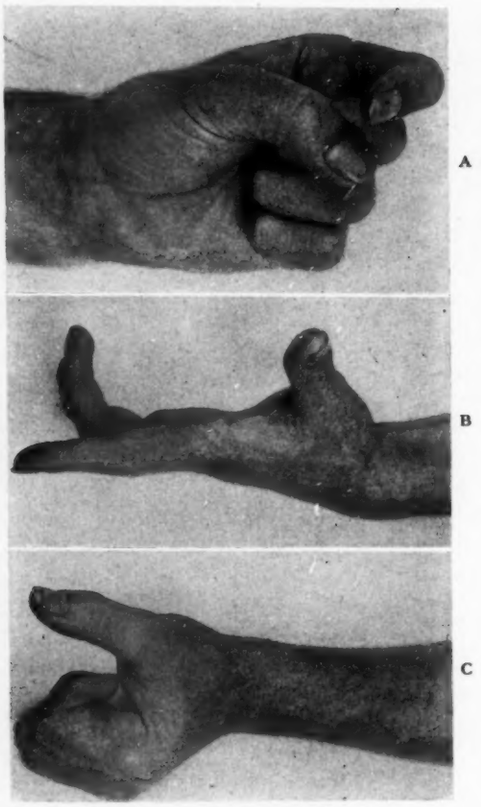


Fig. 10. Case 5. J. B. A, B and C, flexor tendons lacerated at base of index finger. Primary silk repair resulted in a flexion contracture at the proximal interphalangeal joint. Complete interphalangeal joint flexion and extension regained in three months following a free graft.

Fig. 9. Case 4. N. G. A and B, crushing and lacerating wound involving ulnar aspect of palm, severing ring and little finger flexors and ulnar nerve. Nerve repair and free tendon grafts done together. Poor result on anesthetic little finger and good result on partially anesthetic ring finger. Sensation should have been restored to the fingers prior to tendon grafting.

at the terminal phalanx is withdrawn. Passive joint exercises are carried out during the following three or four days and then active flexion is started. During the latter part of the fourth week the patient is instructed to hold firmly in extension the metacarpophalangeal joint, thus transmitting the pull to the proximal interphalangeal joint. (Fig. 4.) If this is not done flexion will be gained only at the former joint. A gripping block made of soft wood 3½ by 1¾ by ⅝ inches is excellent for exercising the finger. Persistent active exercise is important in gaining good finger flexion.

RESULTS

In many patients a near complete restoration of flexor function has been

achieved, in few has a complete failure resulted. An analysis of the failures and poor results shows that generally one or more contraindications to favorable results were involved. However, in one patient the graft was ruptured from its insertion: in another patient, following tendolysis in the palm, the tendon ruptured ten days postoperatively while being exercised. Pressure necrosis disrupted one tendon graft at the proximal pulley.

A total of thirty-six free flexor tendon grafts were placed in the fingers of twenty-eight patients. The principles as outlined by Bunnell were followed in all patients. Fifty per cent of the results were excellent, 32 per cent were good and 18 per cent poor. (Fig. 5.)

In badly crippled hands, a limited range of finger flexion and extension gained through tendon grafting, may be so useful that to classify the result as poor on range alone is unjust. In the otherwise normal hand, however, a finger that does not flex within the good category is a detriment to general hand function.

FIG. 11. Case 6. H. S. A, B and C, compound fracture dislocation of thumb metacarpophalangeal joint with loss of metacarpal head and long flexor tendon. Joint fusion was followed by a free tendon graft from wrist to terminal phalanx; full flexion and extension regained.

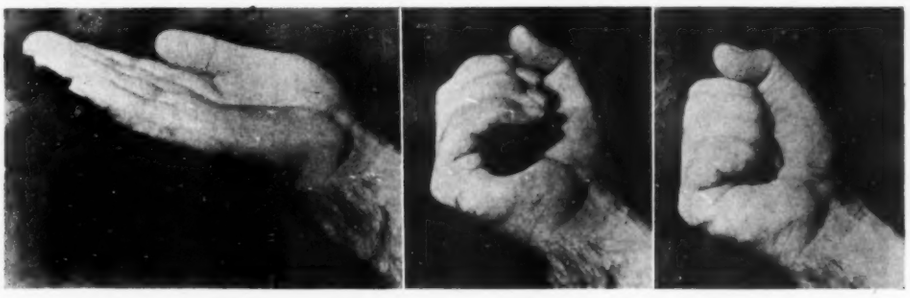


FIG. 12. Case 7. A, B and C, function gained through free flexor tendon graft of the little finger.

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PLASTIC SURGERY IN ACUTE TRAUMA*

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THE surgeon of today whose work includes the surgery of acute trauma must be prepared to use every method that will facilitate the early recovery of the patient, prevent deformities and disfigurement and by so doing restore the patient to his gainful occupation as soon as possible. To this end he must have thorough knowledge of the practical application of the principles of plastic surgery. At the time of the first actual treatment of the wound, regardless of the extent of the trauma, the surgeon should and must visualize the possible end result, both as to deformity and to loss of function. To minimize either a potential deformity or loss of function he must be alert to the use of any and all of the various procedures of plastic surgery which will probably cover raw surfaces that are present. By covering the denuded area one materially cuts down the cicatrix and permits in most cases early active use of the part, with maintenance of function within mean physiologic limits.

At first, such treatment seems far fetched, especially in many cases of severe trauma with exposure of large vessels and nerves that cannot be covered by preference with remaining skin and subcutaneous tissues. However, in these patients the use of a thin or thick split-skin graft immediately results, many times, in a living graft with excellent covering of the previously exposed areas and obviates the necessity for further or later reconstructive surgery. Frequently, this type of coverage is found to be entirely adequate; however, if later for cosmetic reasons it is found advisable, further plastic procedures can still be carried out on clean, closed tissues.

The early use of grafts not only prevents fibrosis with its resulting edema but preserves to a great extent a considerable portion of the lymphatic system, permitting possible regeneration of the lymph vascular channels with their early return of function. These grafts also act as a limiting membrane, preventing fluid loss, the entry of bacteria in the wound and permit early application of pressure to the involved area. In short, skin is the normal and superior cover of the internal tissues. The early and proper use of plastic procedures in surgery of acute trauma involving large defects of skin and soft parts can shorten materially the hospital stay of the patient, to say nothing of preserving the remaining function of the involved part. If not so treated, the function might be markedly decreased by the resultant fibrosis, ankylosis and atrophy which develops if the wound is allowed to heal by the process of granulation and cicatrization.

The principles of plastic surgery gained from the Hindus who first practiced rhinoplasty to the Italian masters of the Renaissance, particularly Gaspard Tagliacozzi; Carpus of England; Graff in Germany in the early nineteenth century and then Reverdin, 1871, in Geneva; Ollier in 1872 in Lyons; Thiersch in 1874 and Wolfe in 1875 in Glasgow have formed the basis of our present day methods. These, of course, have been modified and clarified for present day usage by our own confreres following the teachings of the late Dr. Staige Davis of Baltimore; Dr. Vilray Blair of St. Louis and Gilles, Pickerill and Hunt of England. The past war has permitted the development of a group of young, enthusiastic surgeons who specialize in plastic surgery and who have to a marked degree stabilized our modern methods.

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The ideal and primary principle of all surgery is absolute asepsis. Such wounds or recipient surfaces must be surgically clean. Prior to the use of sulfonamides and antibiotics there was always a question as to whether one had attained such conditions but with the advent of these drugs and the local use of the Carrel-Dakin technic or zinc peroxide (and in the future by other antibiotics, bacteriostatics and bacteriolytics now in development) one may carry on with greater assurance of success.

TYPES OF GRAFTS

The Celsus type, or shifting of the skin and subcutaneous tissue, is often used to cover exposed bone, such as compound fractures of the tibia. The essential factors are maintained of blood supply, proper venous and lymph drainage and sufficient relaxation of the shifted flap to insure circulation. The tension must be minimal and cannot be expressed in figures. The experience of the surgeon and his surgical judgment must be his guide. This type of graft also provides adequate covering for wounds having exposed bones and tendons, as in the forearm, and will prepare an area allowing further surgical procedures such as bone grafting. After shifting a graft the denuded area over muscle, deep fascia and other soft structure should immediately be covered with a thin or thick-split graft.

Free Grafts. (1) Thiersch grafts (epidermal or Ollier-Thiersch grafts). This split graft is generally used to cover the granulating wound surfaces when in the early treatment, by force of circumstance, the wound had to be treated conservatively. This type of graft may also be used to replace mucous membrane since by a certain degree of metapiasia it readily adapts itself to moist surfaces although it never takes on the full characteristics of mucosa. This has been demonstrated by plastic surgeons and in our experience in the employment of grafts used for reconstruction of the nose, the lips and the interior of the buccal cavity. We also have two cases on record in which there was a complete loss of the urethra 1 inch in length, following a compound fracture of the pelvis that functioned nicely by the implantation of such a graft. (The thick-split graft is used more often to cover large defects). This type of graft has good resistance to infection with a minimal amount of contracture.

(2) Full-thickness, Wolfe or Wolfe-Krause grafts. These grafts are used in reconstructive surgery and have limitations but when employed successfully they give the best cosmetic and functional results. Plastic surgeons are developing its use daily. Brown of St. Louis has had excellent results in its application to facial defects.

Pinch Grafts or Reverdin. These grafts are of two varieties, the thin type as first advocated by Reverdin and the thick type known to the modern surgeon as the Davis type. This type of graft is a most useful one and may be used when the circulation is impaired. It is widely used in: (1) directly over the tibia—new or old; (2) severe brush burns of the palms or (3) over an area which must take repeated trauma, as over the end of amputated fingers, toes and metatarsals following a traumatic guillotine amputation of the anterior portion of the foot, or over the heel where cicatrization of surrounding tissues will not permit a full-thickness pedicle graft.

Pedicle Grafts. These grafts may be either free open flaps or the tube types (Italian or Gillws). This type is used when there is need to fill defects of not only cutaneous tissues but subcutaneous tissues and deeper structures. According to the availability of tissue these types of grafts are used either open or closed. The tube graft because of its assured blood supply is very viable and can be twisted and turned quite freely. This permits multiple stage transfers or jump technic.

In this paper we cannot discuss the many and varied procedures for the reconstruction of fingers, thumbs, synoplastic stumps, etc., but must limit our discussion

to the early and intermediate stage of the care of wounds. One must keep in mind, however, that the preservation of the length of stumps which might by the use of tube and pedicle grafts be made to carry a prosthesis at a later date, rather than an immediate closure of a wound with a short and useless stump, is the preferable procedure. Here, we mention the use of the so-called reverse thigh pedicle graft and the delayed reverse thigh flap for such reconstructive procedures.

In this discussion we shall limit the field to that of the immediate covering of skin defects caused by trauma, namely, the phases of débridement and reparative surgery and shall omit that phase of plastic surgery that deals with reconstruction, such as bone grafting and the procedures necessary for free nerve and tendon transplants. We believe the third phase can be largely eliminated or minimized by proper early attention to phases one and two.

VARIOUS PROCEDURES USED IN ACUTE TRAUMA

Soft Tissue Wounds Involving Skin and Little if Any of the Subcutaneous Fat. When there is loss of skin and a portion of the subcutaneous tissue, delayed grafting is indicated with the early treatment of the wound if the tissue does not appear receptive. The treatment here consists of a rational débridement and packing of the wound with thin meshed gauze, either moistened with Dakin's solution or dry, as well as a pressure dressing. After waiting for a period of four to ten days until granulation tissue has developed the skin grafting is carried out. Here, depending on the location of the lesion, either thin or thick-split Thiersch grafts or thick or thin pinch grafts may be used. When there is loss of skin with little or no loss of subcutaneous fat, after proper débridement, immediate grafting using one of the above mentioned procedures may be done.

Superficial Tissue Wounds with Exposure of Nerves, Tendons, Blood Vessels or Bones. When this type of injury is encountered it is proper that following a complete débridement of the wound, an attempt at immediate closure using the Celsus type of skin shift be carried out whenever possible. When by the nature of the wound there is danger of infection or in those patients in whom the wound edges may be sutured for secondary closure following débridement this technic is feasible. Here the interrupted sutures are left long and untied, with dry or moist gauze packs placed into the wound. These are left in place for three, five or seven days until it is believed that by wound inspection and wound bacterial count by direct smear (2 to 4 organisms per low powered microscopic field) infection is not likely, then immediately upon the removal of the packing the sutures are secured and the wound edges approximated. When there is marked loss of substance and complete closure cannot be obtained, the same procedure can be carried out, approximating the skin edges as nearly as possible and filling the defect with either split or pinch grafts. A good rule here is immediate free graft in clean cases and delayed free graft in suspected or so-called dirty ones.

Soft Tissue Injuries with Bone Involvement. In these cases the bone factor is the primary consideration. Following the débridement of the wound the bone must be taken care of with reduction and internal fixation whenever possible. Following this, the early closure of wounds over the exposed bone in compound fractures is today the method of choice of the trained surgeon. When this procedure is carried out it not only converts a compound into a simple fracture but prevents infection and permits early bone union. The more recent the wound the more adaptable the tissues. This can be accomplished by the so-called Celsus graft or shifting of skin and subcutaneous tissues. As a rule, the shifted skin flap should be about 2 inches in width, which allows for sufficient blood supply and closure of a denuded gap of about 4 inches of its great-

est width without tension at the suture line. This, of course, is a matter of surgical judgment. The denuded donor gaps left lateral to the shifted skin and subcutaneous tissue leave a fascial plane that should immediately be covered by free split grafts.

The suture material we prefer is black silk (No. 0 or 1) or nylon (Ethicon, No. 0) to be used according to its needs. Sizes vary when a certain tension is necessary or desired.

Crush Injuries with Traumatic Amputation of Digits. In these cases it is imperative that the surgeon save as much tissue as possible, especially the palmar and plantar surfaces of the fingers and toes. Here, the use of the Z plastic will allow covering with normal skin of those areas that require tactile sensation, pressure sense and permit the use of split grafts to cover the defects on the lateral surfaces. This is particularly true when the palmar surfaces of the thumb and index finger are involved. This procedure is also applicable to traumatic amputation of the foot and hand, when again the plantar surfaces of the foot or the palmar tissue of the hand should be saved if possible, in order to use these in covering over bone ends. However, in other cases when cosmetics are of prime importance grafts should be applied on the stumps.

Crush Injuries with Partial or Complete Evulsion of Skin with Possible Later Resulting Amputation. In these cases it is essential to utilize all vital tissue remaining when an attempt had been made to save the crushed portions of the toe, finger or extremity at the time when first seen. Often in those patients with complete or partial evulsion of the skin when one cannot determine or be sure of the vascular supply, a complete excision of the remaining skin should be done at the base of attachment. Following this complete removal of the underlying fat with replacement of the skin over the vital areas (palm and plantar surfaces), a Wolfe graft with pressure dressings and rest for a period of ten to fourteen days is the method of choice. (Farmer of Toronto has written more extensively on this subject.) This is a meticulous and time-consuming procedure and is useless unless done thoroughly. Here, keenness of surgical judgment will utilize all viable flaps to the utmost. This is a very useful procedure and if plantar or palmar flaps do not cover the defect, thick split, (Wolfe) or pinch (Reverdin) grafts are applied. Another procedure which can be used in this type of case, except in leg and arm amputations, is the shifting type of pedicle graft.

Severe Injuries with Much Loss of Soft Tissue, Including Tendons, Muscle or Bone. Here it is necessary to save all the bone possible, as well as the soft tissue, by a thorough but rational débridement. Following this the denuded area should be covered immediately with skin whenever possible. If a pedicle flap can be swung into the open wound area this should be done immediately so that in five, seven or nine days when the pack is removed from the wound, the pedicle graft can be immediately sutured into position. After healing and take of the graft one has sound tissue to work through when the delayed plastic procedures are carried out on bone and other tissues. At times the area may be temporarily covered with split-thickness graft, converting the open into a closed wound during the periods of waiting for the pedicle graft to develop its blood supply. By use of this early type of pedicle graft one eliminates or limits the formation of scar tissue over the structures upon which later plastic procedures must be done.

It is generally conceded that exposed tendons and cortical bone do not support or nourish split-thickness pinch or other skin grafts; however, we have found in many instances that this assertion does not hold true. Hence, in a fresh wound where these structures are exposed and cannot be covered by the shifting of skin flaps, we have used split grafts directly on tendons, bones, blood vessels and nerves with complete preservation of vitality. The bone

should be irritated to cause minute hemorrhages or revivification which permits the application of thin Reverdin or Thiersch grafts that will obtain adequate nourishment. Here the question of whether to treat these wounds until granulation tissue appears and then grafting, or whether immediate grafting is preferable, has in our minds, been definitely resolved in favor of the latter for by so doing some partially devitalized tissue may be saved. The graft acts as a protecting membrane and permits the deposit of needed nourishing elements, whatever their chemical composition may be.

Soft Tissue Wounds Predisposed to Contracture Deformities Such as Axillary, Groin, Popliteal Fossa and Antecubital Fossa. In these cases the extremities should be immediately placed and immobilized in extension by adequate methods (plaster splints, etc.) with the area covered by thick split grafts in order to prevent contracture of the area. Here the graft should be ample to allow for contraction, so that if later plastic procedure are necessary enough transplanted tissues are available. It is easier to remove an excessive portion of the skin than to replace skin in a contracted area.

PREPARATION OF RECIPIENT AREAS FOR DELAYED GRAFTING

Various methods can be utilized, depending on the condition of the recipient area. In moderately infected wounds dakinization is sufficient for several days. If dirty, infected or superficial slough is present, (aluminum potassium nitrate) poultice to remove the débris followed by dakinization is an excellent preparation. In patients with micro-anerobic infection zinc peroxide paste, as advocated and described by Meleney, has given us excellent results. This has been extremely useful in those wounds that have partially healed by scar tissue with large deep sulci or trench-like depressions extending many times to the periosteum or the cicatrized interior medullary cavity of bones. Its proper use in certain cases that cannot be rendered clean by the usual routine procedure aluminum potassium nitrate (or the Carrel-Dakin technic) will give in three to seven days a clean healthy, firm, granulating surface that can readily be grafted. In addition to this, one has at the present time the systemic use of chemotherapy in the form of sulfa drugs, penicillin and streptomycin. We have not found the local use of these drugs necessary, although we do believe in their systemic use.

TREATMENT OF RECIPIENT AREA AT TIME OF DELAYED GRAFTING

It is imperative that one get good solid granulation tissue. This can usually be obtained by curetting or shaving off the soft superficial layer when redundant or old, exuberant or flabby, insuring a good blood supply for the grafts. One may also use penicillin in solution (40 to 100,000 units in 5 to 10 cc. normal salt solution) injected into and just beneath the granulation tissue underlying the grafts after the grafts have been placed in position. This may also be used in fresh wounds. The tissue surrounding the grafted site may also be injected with this solution. Heilman, et al., have reported excellent results with this method of treatment and we have used it with good results. It is worthy of trial and observation in those cases that are questionable as to sterility of the granulating or recipient surface and it is good in primary and delayed grafting.

Early treatment of any type wound which may involve subcutaneous tissues, fascia, muscles, blood vessels, nerves, tendons or bones and in which there is a loss of protective skin covering, requires the usual thorough débridement with the minimal amount of surgical trauma and the establishment of complete hemostasis. This is carried out by the use of the Carrel-Dakin technic and the so-called non-touch Lane technic in compound fractures. Surgical judgment will tell one how much of the skin wound can be closed by suture; it will also tell one if the residual denuded

area consists of viable tissue, fascia, vessels, nerve, tendon, bone, etc., and if the contamination of these tissues has been kept at a minimum. If these objectives have been obtained, the areas should immediately be covered by grafts of proper choice and maintained in position by a firm compression bandage of a type most effective with the operation. At no time should strong tissue-devitalizing antiseptics be employed in or about the wound or the donor area. The donor area can readily be dressed by covering it with simple flamed adhesive plaster, plus a pressure dressing.

The foregoing are elective methods used on our service—these have been screened from reading the literature of our predecessors, personal observation and frequent contacts with our confreres over the past thirty years.

Operation for harelip is usually indicated in early infancy. The deformity is always distressing to the parents and should be repaired as early as possible. Early repair of a cleft lip will minimize lip and nose deformity and aid in molding a coexisting deformity due to a cleft of the alveolar process.

From "Operations of General Surgery" by Thomas G. Orr (W. B. Saunders Co.).

PLASTIC SURGERY IN INDUSTRY*

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DURING 1945, there were 2,000,000 accidental injuries and 16,000 deaths in American industries. Accident costs alone were $600,000,000 and the total cost to industry was three times that amount.[12] It is small comfort that there were more workers injured in accidents outside industry. Obviously, accidental injuries sustained in industry, therefore, are a problem of great magnitude. The work done by the industrial surgeons in caring for the injuries and directing the rehabilitation of the injured workmen is a matter of pride for the entire medical profession.

Our purpose in writing this paper is to stress the importance of the principles of plastic surgery as an aid to the industrial surgeon in this work.

GENERAL CONSIDERATIONS

Three important factors must be considered by the surgeon confronted with a traumatic wound; time of injury, the nature of contamination and the extent of the wound.

Time of Injury. Probably the most important factor is the duration of the injury at the time repair is to be performed. To be sure, this is more vital in wounds involving tendons than in wounds of the face but it must be considered at all times. It is generally agreed that wounds of the face can safely be repaired at any time within eighteen to twenty hours after injury and that soft tissue injuries elsewhere on the body should be repaired within eight to twelve hours. We have arbitrarily limited primary repair of tendons to those patients seen within four hours, as recommended by Mason.[10] Repair of flexor tendons, particularly of the fingers, should not be attempted after two hours because of their location in a firm fibrous canal. Infection following repair in this area is particularly disastrous, both from the standpoint of resultant limitation of function and the difficulties encountered in obtaining satisfactory results through secondary repair following such infections.

The possibility that the local and systemic use of the newer chemotherapeutic agents may alter this factor is to be considered but we are inclined to adopt such a trend with caution.

Nature of Contamination. The nature of wound contaminants is of great importance in making a decision to perform a primary repair, particularly in compound fractures and wounds involving tendons and nerves. Alpha and beta hemolytic streptococci and coagulase—positive Staphyloccoccus aureus, the organisms which are responsible for the bulk of severe infections, are rarely introduced into a wound at the time of injury. These usually are from a human source and are introduced later from examining fingers, mouth spray, dust from the ward or dressing rooms or from unsterile first aid dressings, such as soiled handkerchief. This is, of course, exclusive of tetanus and gas-forming organisms.

Extent of Injury. Occasionally, the patient has sustained multiple injuries and his general condition does not permit primary repair of those injuries which are the concern of the industrial surgeon or the plastic surgeon. This factor also includes the local extent of a wound—can it be repaired in the office or plant operating room or should it be done in a hospital?

Secondary repair of wounds is necessary because of poor cosmetic or functional results or because primary repair at the

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time of injury was not advisable. The plastic surgeon must consider the manner in which the wound healed, the degree of impairment of function and the condition of surrounding soft tissues before electing to perform a secondary operation. Wounds healing by primary intention may be revised in three to six weeks. When infection has occurred an interval of four to eighteen months should be allowed. A complete loss of function should be corrected as soon as possible. Finally, it may be necessary to remove scars and provide normal skin by swinging flaps or to perform a skin graft before secondary repair of deeper structures can be attempted.

Anesthesia. Local anesthesia should be employed whenever possible. This may be affected by infiltration or by nerve block. Five-tenths to 1 per cent novocaine containing five to six drops of adrenalin chloride to each ounce is a safe local anesthetic. Smaller quantities of a 2 per cent solution may be used for nerve block but the 1 per cent solution is usually sufficient. A 4 per cent solution of cocaine used topically is a useful adjunct in surgery of the eyelids, nose and mouth.

SOFT TISSUE INJURIES

Soft tissue injuries cause the greatest concern when they involve an area of the face. The principles governing the surgical repair of such wounds in our clinic may well be adapted to soft tissue injuries of any part of the body. The so-called "plastic closure" of operative wounds has been used by some general surgeons with excellent results.

After a thorough examination has shown the injury to be limited to the soft tissue, cleansing is affected by a thorough scrubbing with green soap and water. Care is used to cleanse the surrounding skin first; then after anesthesia is obtained the depths of the wounds are cleansed. The wound and the adjacent areas are thoroughly irrigated with sterile water. The skin surfaces are sponged with alcohol and the area suitably isolated with sterile drapes.

Our method of closing lacerations is by no means original or unique. When the wound is jagged, so that a fine closure cannot be obtained, the skin edges are trimmed and straightened. Excess subcutaneous tissue is excised and the skin

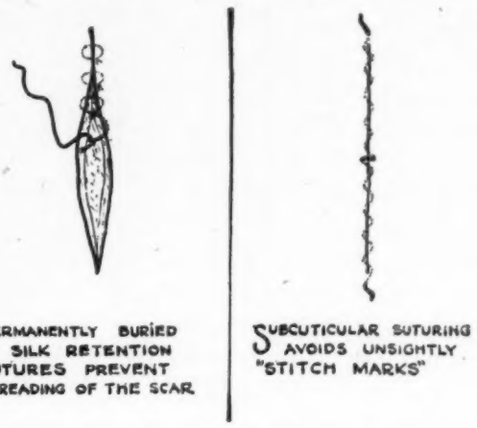
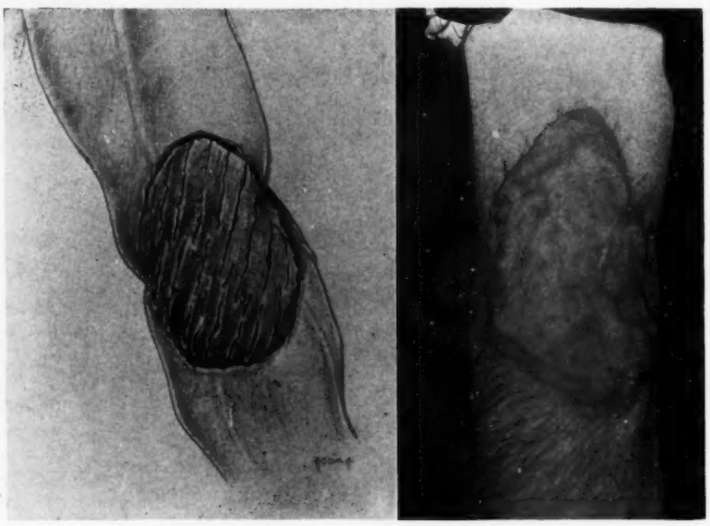

PERMANENTLY BURIED SILK RETENTION SUTURES PREVENT SPREADING OF THE SCAR
SUBCUTICULAR SUTURING AVOIDS UNSIGHTLY "STITCH MARKS"

Fig. 1. White silk, inverted, vertical mattress sutures close the subcutaneous tissues, with the knot deep in the wound. Subcuticular sutures oppose the skin edges accurately, eliminating suture marks.

is undermined for a sufficient distance in all directions so that the skin edges may be coapted without the slightest tension. Absolute hemostasis is accomplished by pressure and through the use of white silk ligatures. Black silk is never buried since it sometimes results in visible dark markings under the skin.

The subcutaneous tissue is then closed by means of an inverted vertical mattress suture of white silk with the knot in the deepest extent of the wound. If these sutures have been correctly placed the skin edges should be in apposition. A subcuticular suture (Halstead) of No. 0000 or No. 000000 nylon (or occasionally fine stainless steel wire) is used to assure perfect alignment of the skin with slight eversion and usually a few interrupted horsehair sutures are inserted and tied with one double twist knot. (Fig. 1.) Occasionally, in small wounds two continuous sutures of horsehair or nylon are used, the first serving to close the subcutaneous tissue and the second to close the skin. It is advisable to bring the subcuticular suture



A B

FIG. 2. A, artist's drawing of injury incurred when arm was caught in some gears. The shredded skin was attached only by a small pedicle at the medial margin. On the operating table, the skin became cyanotic and was immediately excised. A split-thickness graft was applied; B, healed skin graft. The period of disability was greatly decreased and the functional result was excellent.

to the surface about every 1½ inches in longer wounds. The external loops can be cut and the sutures removed in sections with greater ease.

Such a method of suture completely eliminates the possibility of unsightly suture marks. The horsehair sutures are removed on the second or third day and the nylon subcuticular suture is removed on the tenth day, although it may be left undisturbed for a longer time.

The closure of wounds in which there is loss of substance may tax the ingenuity of the surgeon. Skin grafts may be necessary to preserve the function of exposed tendons but such a procedure is used on the face only as a last resort after all other methods of closure have failed. They are, however, sometimes used to facilitate healing and are later excised. When a wound is so badly torn that the skin is not viable it may be completely excised and a skin graft applied. In such an instance (Fig. 2) a patient's arm was caught in some gears. The shredded skin was partially sutured but became cyanotic before the repair was completed. The injured skin was removed immediately and a split-thickness graft was applied. A complete take resulted.

Wounds involving both skin and mucous membranes, such as those seen in the lips and cheeks, are immediately approximated by a figure of eight suture of No. 0000 nylon with the knot tied in the mouth. This type of suture eliminates the need for any tension in the skin sutures. By the tenth day all sutures have been removed leaving none in the depths of the wound. The mucous membrane is so loosely closed by this method that drainage is adequate should infection develop.

Lacerations of the tongue heal well and simple care in the suturing is the only requirement. Anesthesia can be accomplished easily by nerve block.

Injuries to the eyelids present special problems because of the marked deformities resulting from very slight contractures. It is essential that the palpebral margin be in perfect alignment. The first suture is placed in order to accomplish this. The points of entrance and exit are selected approximately 3 to 4 mm. on either side of the laceration just posterior to the cilia near the grey line.

This suture when tied also supplies an excellent means of traction during the rest of the repair. The conjunctiva is closed

with interrupted black silk sutures. The skin, muscle and tarsal plates are approximated with interrupted horsehair sutures.[17] Kazanjian[7] and Spaeth[19] advocate suturing a verticle laceration of the lower lid in a series of Z-plastics so that the skin sutures are offset from the muscle and conjunctival sutures. They believe that subsequent contracture is thereby minimized.

The nasal skin, because of the enlarged pores and excess secretions over the tip of the nose, presents a serious problem when lacerations occur in this area. Healing is frequently complicated by infection and resultant scars are unsightly. Closure can best be accomplished by the use of a subcuticular suture and interrupted horsehair sutures. When the cartilages of the nasal tip are involved the mucous membrane requires suturing only when the structure of the nose has been markedly distorted. Frequently, nasal packs of vaseline gauze will suffice to maintain the mucous membrane and cartilage in position until healing is well under way. These can be removed on the fourth or fifth day.

Lacerations of the external ear are mentioned primarily to voice a word of caution. The healing powers of the pinna are remarkable and it is rarely necessary to débride any part of its tissue. It is far better to attempt a repair, no matter how hopeless it may appear and remove necrotic tissue later if necessary.

We recently cared for a young man who had been in an accident in which his right ear was severed completely and later recovered. The skin was removed and the cartilage was embedded in a pocket formed under the postauricular skin in the proper location for the missing portion of the ear. After an interval of two months the reconstruction will be continued as proposed by Kirkham.[8] Any simple primary repair necessary should include every effort to leave the postauricular skin as free of scar as possible so that it may be used later in any necessary reconstructive measures.

Abrasion of the skin frequently accompanies other injuries, and if not properly cleaned, may result in an extremely disfiguring scar not unlike a tattoo mark. Such an area should be thoroughly scrubbed with a brush, soap and water. Deeply embedded particles of grime should be picked out with a pointed knife or another sharp instrument. A suitable dressing is very like that applied to a burned area, using a bland ointment. Sandpaper can be used to smooth the surface of an abrasion and remove cinder or powder marks. Dupertius[4] has recently described his method of using small free ear lobe grafts comprised of skin and subcutaneous tissue as a means of replacement of the fat pad of the finger tip.

Painful and disfiguring scars at the fingertips which prevent normal growth of the nail are frequently seen. Douglass[3] has reported a method of repair which he has used successfully. The deformed nail is removed completely and the eponychium is dissected free in the sulcus over the nail root. The scar tissue at the fingertip is undermined, leaving an attachment at either side. An artificial fingernail, such as may be obtained at any cosmetic counter, is inserted under the scar tissue into the dissected sulcus. Sutures are placed through previously drilled holes. The artificial nail is left in place until the new nail has grown under it out over the scar tissue. When the artificial nail is removed the scar tissue band is excised.

Douglass[3] has also successfully replaced the amputated tips of fingers in four patients. Several years ago Gillies suggested embedding amputated fingers in the abdominal wall after the skin has been removed. The finger was to be reattached to the stump and covered by abdominal skin through a series of delayed flaps. The suggestion is offered here in the hope that it might be successfully used in a suitable circumstance.

NERVE AND TENDON INJURIES

Tendon and nerve repair should not be attempted unless the wound is seen within

four hours after the injury occurred. When the wound has been previously tampered with (in a physician's office or a company first aid station) even to the ligation of vessels, the wound is closed as simply as possible and a secondary repair is done after healing has occurred. First aid should be limited to the application of a sterile dressing and a splint, bleeding being controlled by pressure or by application of a tourniquet rather than by ligatures.[10]

When the tendons have been repaired complete closure of the skin over them is mandatory. When necessary this may be done with skin flaps[9] or with skin grafts. This is a very important procedure for all surgeons to know—it may save months of time and it may save the function of the hand.

FRACTURES OF FACIAL BONES

As a general rule, fractures of the facial bones should be corrected early. Impactions can be broken with relative ease during the first week but the difficulties increase rapidly after a greater interval as does the danger of infection. We have found that repair of maxillofacial injuries does not add risk to the patient with major cerebral, thoracic, abdominal or extremity injury. The exception is if the cribriform plate has been fractured. Immediate facial surgery is indicated for with delay, in addition to tissue loss due to trauma, there is added loss due to infection and retraction. Therefore, as soon as the extent of injury is evaluated and treatment begun the facial repair should be performed.

In our clinic a systematic routine of examination has been adopted. Facing the patient and palpating bimanually the frontal bone is examined for fractures. Then the fingers pass over the supraorbital rim laterally, around to the infraorbital rim and back to the nose, comparing the two sides. A displaced zygoma and irregularities of the orbital rim will be immediately apparent. The eyelids are separated and the cornea and conjunctiva are inspected. If there is any visual disturbance, an ophthalmologist is consulted. The nasal bones are next examined for asymmetry or crepitus and the condition of the septum and the lateral wall is determined by intranasal examination. The lips are separated and the teeth are checked for malocclusion and displacement of the alveolar ridge. When the maxilla is fractured movement of the entire compound or fragments can usually be elicited; however, if impaction is severe this may not be possible. Further observations supporting a diagnosis of fracture of the maxilla are widening or lengthening of the middle of the face and displacement of the orbital contents due to loss of support. The examination of the mandible is the last step. After observing the patient's ability to open and close his mouth the temperomandibular joints are palpated, noting the presence of tenderness or crepitus when the mandible is moved. The fingers are then passed down the posterior border of the ramus thence to the body and the mentum. With the thumb within the mouth and fingers behind the ascending ramus holding the jaw firmly, abnormal movement in the mandible may be detected by moving the chin up and down with the other hand.

X-rays of the skull should be routine procedure and although *x*-rays of the facial bones are usually not necessary they are of great value from a legal standpoint.

A detailed discussion of the treatment of fractures of the facial bones is impossible in a symposium such as this. However, a few important points will be touched upon in the fractures of the various bones.

Frontal Bones. Fragments of the frontal bone may sometimes be pried directly into place when the fracture is compounded. Also, the fracture may be approached through the sinuses and the fragments elevated with a chisel. We have on several occasions inserted an ordinary wood screw into the fragment, elevated it by direct pull and where necessary held it in position by attaching it with a wire to a solid arm embedded in a plaster of paris head cap.

Nasal Bones. Fractures of the nasal

Fig. 3. The Straith appliance for treating depressed fractures of the nasal bones includes an adjustable assembly for elevating the nasal bridge and compressing the sides of the nose. The supporting post is embedded in a plaster head cap.

bones may be a simple lateral displacement or a crushing fracture of the nasal bones and the maxilla, lachrymal and ethmoid bones. In the first instance, simple elevation is accomplished with a flat instrument such as a chisel or periosteal elevator. The fragments are molded into position and if necessary the nasal cavity is packed with vaseline gauze to support them. There have been numerous methods suggested for the treatment of the more severe crushing injuries of the nose, many of which are satisfactory. We have our own apparatus consisting of two rubber covered metal rods which are inserted into the nares and two flat metal pads which may be adjusted to press on either side of the nose. This unit is fully adjustable and is supported by a bar on a plaster head cap. (Fig. 3.) The elevating pressure within the nose can be adjusted by means of the thumb screws and a universal joint; the pads prevent spreading of the fragments.

Malar. Padgett made the statement that fractures of the malar bone without a complicating fracture of the surrounding bones occur rarely.[15] Usually the malar

Fig. 4. *X*-ray showing maxilla held up by buried, stainless steel wires passed from small drill holes in the frontal process, down behind the malar bone and fixed to teeth in the mouth.

bone is simply driven in, great force being required to produce this fracture. The pathognomonic sign of fracture is depression of the bone but swelling may make the diagnosis difficult. Distortion of the orbital rim as compared to the uninjured side, anesthesia of the upper lip, the infra-orbital area and side of the nose due to compression of the infra-orbital nerve, together with enophthalmus or diplopia are additional findings aiding in making the diagnosis.

Correction of the deformity is relatively simple if attempted within the first week. Roberts[16] suggested using a screwporte inserted through a small incision to elevate the depressed malar bone. The well known method of Gillies is frequently used—an incision in the temporal skin and fascia is made and a Gillies elevator or a flat chisel inserted downward along the tem-

poral muscle deep to the displaced bone. Lever action over a pad on the side of the head will elevate the bone.

The approach usually used by our group is made through a small incision in the buccal fold opposite the second molar tooth. A Cryer elevator is inserted (a chisel or large hemostat may be used) and the impaction is broken up. The bone may then be wedged into place with external pressure by the other hand. When the anterior wall of the antrum has been crushed it may be necessary to fill the cavity with gauze impregnated with vaseline or tincture of benzoin as support for the malar bone. The packing may be left in place for a week without risk. In badly comminuted fractures wiring of the malar bone to the frontal process is very useful.[6]

Maxilla. It has been suggested that surgically the maxillary bones include the malar, the palate, the inferior turbinates, the lachrymal, the nasal, the lateral masses of the ethmoid and the nasal septum, as any or all of these are likely to be involved in injuries characterized as fractures of the maxillary bones. Fractures of the maxillary bones may include the alveolar processes, the palate or the superstructure proper. We do not recommend the use of any method requiring intermaxillary wiring in severe injuries resulting in extreme nasal congestion.

Some of our more recent patients have been treated by the internal wiring method as outlined by Adams.[1] (Fig. 4.) A double stainless steel wire is looped through a drill hole in the infra-orbital rim, if it is uninjured, or through a drill hole in the zygomatic process of the frontal bone. The ends of this wire are passed posterior to the malar bone and into the mouth. If the alveolar process is intact, the wires are attached to the premolar teeth and tightened sufficiently to support the maxilla in its place. When the alveolar process is fractured a silver arch bar is first attached to the teeth and traction is then applied to the bar.

We have also obtained good results with Fiederspeil's method of passing wire attached to the teeth superiorly and anteriorly through the check to a framework embedded in a plaster head cap.[5] This method provides better traction for those patients in whom the maxilla is displaced posteriorly as well as downward but the patient is subjected to the discomfort of the head cap.

Mandible. Numerous dental splints have been devised for fixation of fractures of the lower jaw but they are difficult to make and apply. Complete immobilization of the lower jaw can be simply accomplished by wiring the teeth to the teeth of the upper jaw. No external splints or bandages are necessary. When the mandible is edentulous the wires may be passed around the bone and the prosthesis or a molded splint and the intermaxillary wires applied.

In general, fractures of the ramus and the body of the mandible are easily treated by simple intermaxillary wiring. It is generally agreed that fractures of the neck of the condyle are best treated conservatively, with the theory that if union does not occur a false joint will be formed which will function adequately. Padgett[14] stated that when the fracture is high the condyle may be removed and that when it is near the ramus open reduction may be done.

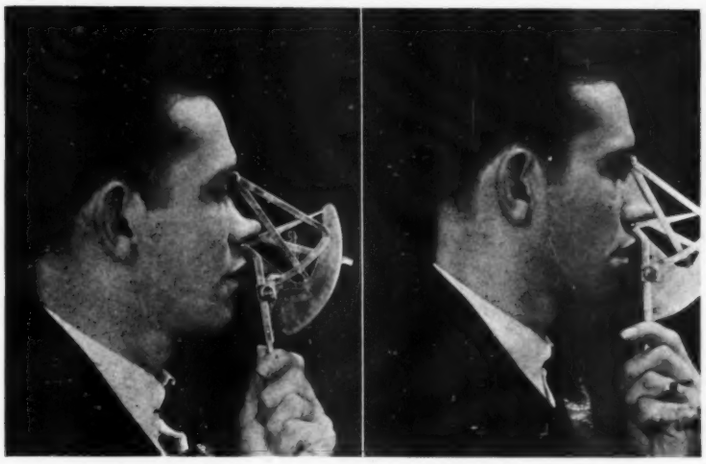
Fractures at the angle are difficult to manage. When the ramus has been pulled too far forward a wire loop may be placed through a hole in the posterior part of the angle and attached by an elastic band to a plaster head cap extending down over the mastoid region.

LATER CARE OF FACIAL INJURIES

The procedures useful to the plastic surgeon in the late care of facial injuries fall into four groups and may be used singly or in varying combinations: (1) excision of scars; (2) substitution of soft tissue or bone; (3) camouflage by addition of various substances and (4) artificial internal or external prosthesis.

A B C

FIG. 5. A, crushing injury with heavy weight fifteen years before resulted in wound shown above which would not heal under usual treatment. Split-skin grafts had not been successful. Flap on opposite thigh has been delayed and is ready for transfer; B, "cross-leg" flap sutured in place before plaster cast was applied; C, healed graft, providing skin which is normal in all respects. Such a graft will withstand trauma better than split-thickness skin grafts.



A B

FIG. 6. A, the Straith profilometer, when set at normal, indicates the amount of cartilage necessary to reconstruct the nasal bridge; B, showing normal measurements on profilometer after cartilage transplant.

Soft Tissue. All too frequently disfiguring suture marks mar an otherwise satisfactory repair of injuries of the facial skin. They are very difficult to correct for their complete removal necessitates excision of an excessive amount of skin. The careless use of large suture material and failure to remove the sutures early are the primary causes of such scars.

Scars resulting from wounds from which tissue has been lost may be excised and the wound closed in a fine scar if small enough. Such scars have usually contracted severely and the relaxation of the tissues after removal of the scar frequently results in a wound several times larger than the original scar. Replacement of skin by skin graft, Esser (swinging) flaps from adjacent areas or by tube pedicle from distant areas may be necessary. The transfer of skin from other parts of the body to the face is seldom completely satisfactory since the color and texture is never the same as that of the facial skin. However, the postauricular and neck skin is often quite similar and replacements from these areas are not particularly noticeable.

For the transfer of skin and subcutaneous tissue short distances to fill defects, cover tendons and to replace scar tissue on weight-bearing surfaces, the simple pedicle flap may be used. (Fig. 5.) It is advisable

to skin graft the donor area and the raw surface of the pedicle to decrease the amount of drainage. Flaps may be tubed to transfer tissue to more distant areas.

Fractures. Depressions in the frontal bone following fractures are occasionally

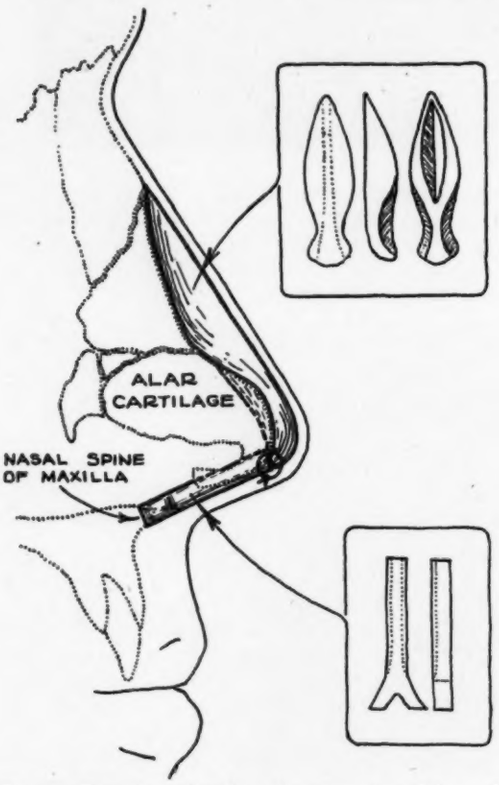


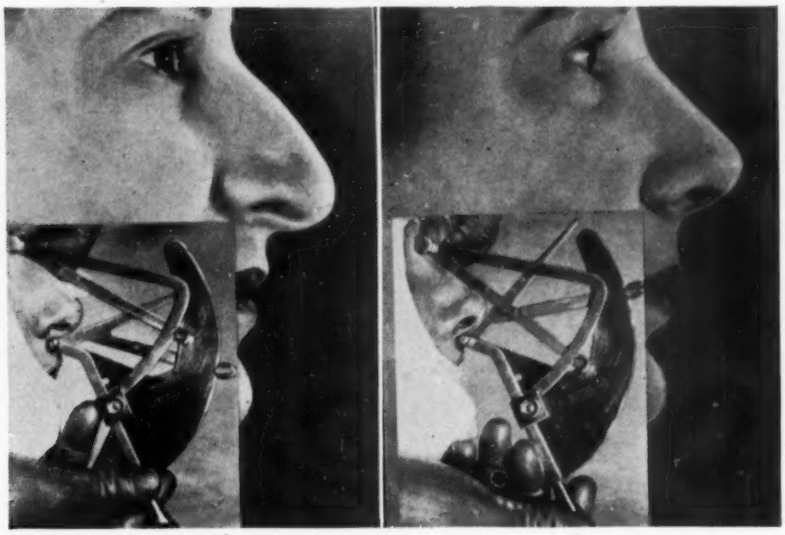
Fig. 7. Drawing showing shape and position of cartilage transplants in reconstruction of nasal bridge. A post for support of the nasal tip is shown resting on the nasal spine of the maxilla.

seen and although they may cause no functional disturbance they are extremely disfiguring. Preserved cartilage can be used to fill such defects, either as a carved solid piece or as diced or pulverized cartilage. An incision is made in the eyebrow or in one of the normal skin creases of the forehead and the skin is elevated throughout the entire defect. It is tedious and difficult to shape a solid piece of cartilage to fit a defect of the frontal bone. When too thin a piece is used it frequently curls and the edges become visible under the skin. The same objection holds with shaved cartilage; therefore, we have been using finely cut or pulverized cartilage, injected into the prepared pocket under the skin with the De Kleine Chondrajet.[2] The cartilage can be molded into shape after the incision is closed and a pressure dressing is applied to prevent hematoma formation.

Fractures of the nasal bones may result in a marked deflection deformity of the nose, a saddle nose or a hump nose with a depressed tip. A rhinoplasty will correct the deflection deformity or a marked hump on the bridge of the nose. Even in a saddle nose, it is often better to perform a rhinoplasty first, and later to attempt some method of restoring the bridge to normal pleasing proportions. Various methods of reconstruction for saddle nose have been developed, such as the use of autogenous rib cartilage, the use of a piece of the crest of the ilum and the implantation of ear cartilage. O'Connor and Pierce[13] have developed a method of preserving cartilage and have shown that preserved homologous cartilage can be used for such purposes.

For the past twelve years, all saddle nose deformities treated in our clinic have been corrected by the implantation of preserved homologous rib cartilage. Prior to that time autogenous cartilage had been used but one or two unfortunate experiences with the chest wound prompted the adoption of the preserved cartilage transplant.

The Straith profilometer (Fig. 6) is used to measure the amount of depression in a saddle nose and to indicate the shape and size of the cartilage transplant needed. A straight firm piece of cartilage containing no calcified areas is selected. It is cut to the proper length and thickness to form the bridge of the nose. This is inserted through a columella incision into a subcutaneous tunnel along the bridge of the nose. Where necessary a second smaller piece of cartilage is shaped as a supporting post within the columella. (Fig. 7.) This piece has a forked base which will rest upon the maxillary spine, the upper end having been shaped as a tenon to fit into a mortised joint in the first piece of cartilage. The profilometer is also of great value as an



A B

Fig. 8. A, illustrating use of profilometer in treatment of hump nose. The amount of tissue to be removed is measured before the operation, and frequent measurements are taken during the operation; B, postoperative result.

A B

Fig. 9. A, scars of both hands resulting from burns; B, showing result of skin grafts after complete excision of scars.

aid in reducing hump noses to the proper profile angle. (Fig. 8.) It makes the reconstruction of nasal deformities more accurate.

Untreated impacted fractures of the malar bone result in distortion of the facial contours and in visual disturbances. Solid preserved cartilage or diced cartilage may be used to restore the malar eminence.

Healed, retruded fractures of the maxilla may be freed with a mallet and chisel and held in place with proper wiring.

BURN SCARS

Plastic surgery as a specialty is more often concerned with the treatment of old healed burns and the resultant disfiguring scars and deforming contractures. Such scars are commonly seen on the anterior surface of the neck, the axilla, the anticubital and popliteal areas, near the eyelids and the mouth and on the face. Severe burns of the hands and feet result in disabling scars. Many scars can be completely

A B

FIG. 10. A, web contractures of both axillae, preventing full use of the arms. The severe contracture has resulted in an ulcerated area on the back ; B, restoration of function by massive Z-plasty's. The ulcer healed rapidly after tension was relieved.

excised and replaced by split-thickness skin grafts. (Fig 9.)

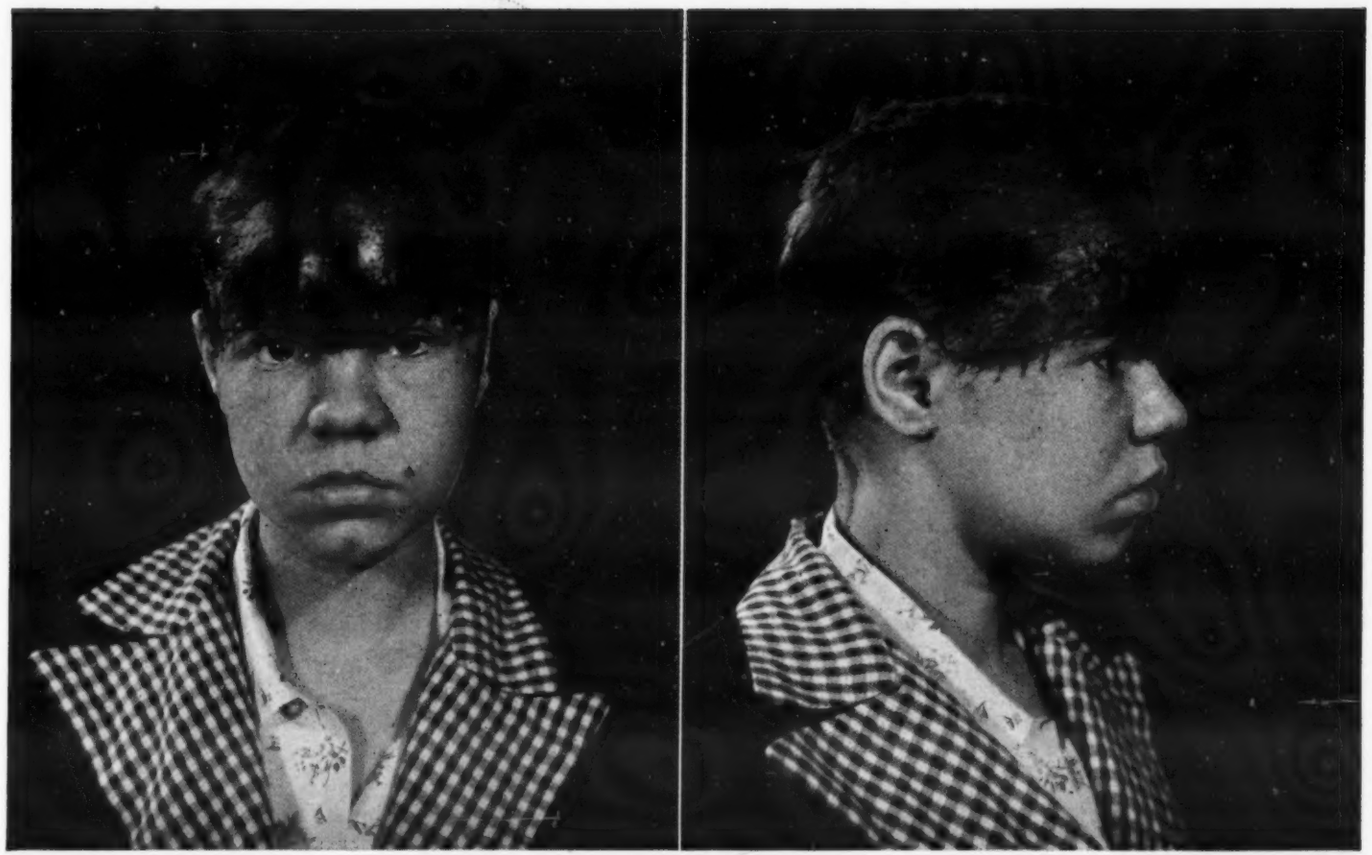
The Z-plastic operation is one of the most useful and valuable procedures available to the surgeon in the treatment of scars and contractures anywhere about the body and should have first consideration. (Fig. 10.) Smith[18] has shown the wide variety of uses of this simple procedure and the excellent results obtained with it in his hands.

FIG. 11. Note conspicuous keloidal scars on legs of young girl resulting from unfortunate choice of donor sites for skin graft. When possible, skin should be taken from the abdomen.

Many scars which are too large to permit complete excision and closure in one procedure may be ultimately removed in a number of partial excisions. The normal surrounding skin can be advanced as much as possible, then as relaxation occurs further excision is possible until only a fine linear scar remains.

Cicatricial ectropion of the lower eyelid causes epiphora and irritation of the exposed conjunctiva; ectropion of the upper lid results in lagophthalmus which if marked may lead to loss of the eye. Such deformities can largely be prevented by adequate early treatment of the burn and early skin grafting. The importance of careful consideration in the choice of donor areas should not be overlooked. This is particularly important in young women. (Fig. 11.)

Several satisfactory procedures are available for correction of cicatricial ectropion. The destroyed tissue may be replaced by (1) flaps from the nasal or temporal border of the lid or (2) correction of the defect by full-thickness graft of skin from a normal lid or of skin from the medial surface of an ear. The epithelial outlay of Esser does not produce so pleasing a cosmetic result as does the method introduced by Wheeler, in which surgical adhesions are made between the upper and lower lids after which the graft is sutured



A B

FIG. 12. A and B, Miss M. J. T., aged nineteen, a war worker, had total scalp avulsion when a wisp of hair was caught on a revolving machine. The hair was cut off, and the scalp was replaced by the industrial surgeon and fixed by sutures. Unfortunately the scalp became necrotic as shown here eighteen days after the accident. Four days later the necrotic scalp was removed surgically by us.

C D

FIG. 12. C, a clean vascular granulation is shown three weeks after removal of the necrotic scalp. The patient is ready for skin grafts. The entire granulating area was grafted at one operation, with thick split grafts united by sutures and clips and rendered adherent to the recipient bed by fibrin fixation through use of Thrombin Topical solution and blood plasma. D, the patient is shown after the operation. The paraffin mesh gauze dressing was fitted snugly over the grafted area and sutured to margins of the defect. No other pressure dressing was required. Patches of pink color may be seen which began to appear over the graft in thirty-six hours.

E F

FIG. 12. E and F, two views of the patient are shown on the eleventh postoperative day, immediately after removal of the paraffin gauze dressing. The grafts show almost complete and successful take. Fibrin fixation of skin grafts with Thrombin Topical solution and blood plasma facilitates management of skin-grafted patients and materially enhances the probability of successful results.

G H

FIG. 12. G, the patient is shown eight months after the operation. The grafted scalp is entirely healed. The graft over the temple was done later when epithelized area was found to be unstable. The new eyebrows were grafted two months after plastic repair of the scalp defect. H, the patient wearing a wig made from the hair which was removed from her avulsed scalp. The total period of hospitalization was only seventy-eight days.

A B

FIG. 13. A, chemical burns caused total loss of the right ear and destruction of the skin over most of the right side of the face. Early skin grafting is necessary to reduce scars and contractures; B, a split-thickness graft was applied to the side of the face. Note heavy scars at margins of the graft and contracture of the right ala. Scar tissue in the region of the ear makes reconstruction of the ear difficult.

in place. The surgical adhesions remain for sixty to ninety days.

Severe burns of the entire face with loss of eyebrows and eyelashes and its associated scars present one of the most heart rending problems in the field of industrial and plastic surgery. The release of contractures, replacement of scar tissue with skin grafts and the necessary trimming and fine adjustments offer a seemingly endless procedure which may continue over a period of years. Although the unfortunate patient will never be completely satisfied it is possible to bring about great changes and improvement. (Fig. 13.)

SCALP WOUNDS

A paper dealing with the treatment of industrial accidents would not be complete without some reference to one of the most terrible accidents which may occur in modern industrial plants—the irremediable loss of a young woman's hair through complete scalping. The accident is sufficiently rare that the patient is very likely to fall into the hands of physicians who have never dealt with the condition.

The accompanying illustrations (Fig. 12) show the course of such a patient.[20] A lock of unprotected hair was caught in revolving machinery and the scalp was completely torn away. The scalp was recovered, the hair cut off and saved and the scalp was sutured in place by the industrial surgeon. The entire scalp became necrotic in eighteen days, was removed and the granulating surface was later covered with split-skin grafts held in place by Thrombin Topical* and plasma.

McWilliams[11] collected forty cases of replacement, all unsuccessful. Since the scalp is a complex organ with an arterial blood supply death is certain when the blood supply is destroyed. Anatomically, simple replacement would appear to be hopeless.

* Supplied by Parke Davis & Co.

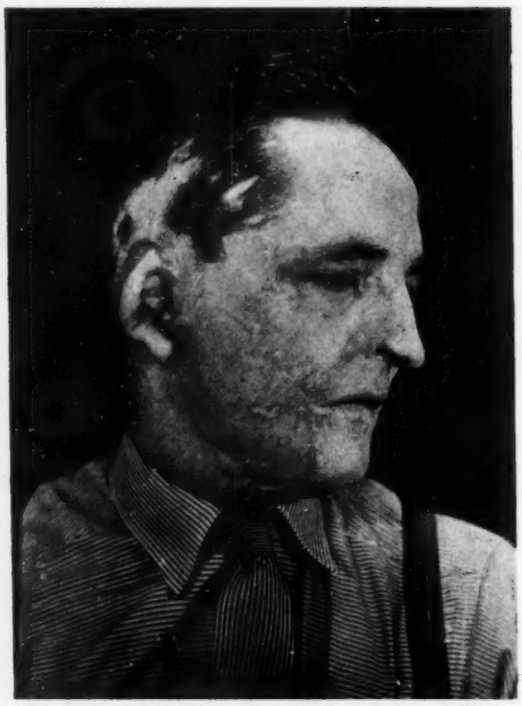


FIG. 13. C, excision of scars has improved the right cheek and mouth. A full-thickness graft was used to release the contracture of the right ala, and a semblance of an ear has been reconstructed from the scar tissue and a tubed pedicle from the chest.

It is suggested that the avulsed scalp be shaved, split and the upper hairbearing surface be replaced as a full-thickness graft. We realize that this theory may not prove practical but if we ever have another opportunity the scalp will be treated in this way. However, the records of the past and the law of averages make this unlikely. We can only hope that this suggestion may help some surgeon to save a human being from similar permanent disfigurement.

The wearing of hair nets by women employees should be mandatory.

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RECONSTRUCTIVE SURGERY OF THE INJURED NAIL

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THE importance of the hand has been compared with that of the brain in human economy. However important may be the brain, the functional efforts consummated by the hand are so imperative for maintenance of life and the creation of new things of life that the hand makes a fair bid for the supreme station. As life becomes more and more industrialized the uses of the hand become more manifold and highly specialized. It is natural also with the increased use of the hand and the increased speed of modern industry that the hand is liable to more frequent injury than any other part of the body. Industrial injury demands immediate consideration of the states of present and future disability. In other words the full mechanism of workmen's compensation is placed in motion. It is to the employee's, employer's and the insurance carrier's benefit to get the worker back to work with as little permanent disability as possible in the shortest period of time.

Most states have set up elaborate schedules and fee tables to cover most all traumatic work; however, there is no state at present that recognizes deformity or loss of a nail as a disability, either partial or total. A disability may be defined as "the inability to work with the same degree of ease and comfort as before the injury was sustained." Only two states recognize disfigurement of the hand as a compensable disability. If the injured digit is considered when all joints are functioning and the nail only is deformed or a vestige of its former self, it would require a very callous referee and doctor to swear there is no permanent disability. There is a disability, especially if the hand has been trained for delicate precision work or if it is employed in the arts of acting or modeling. It is certain that the ever present disfigurement as well as the dysfunction initiates the verdict of a permanent disability. Any procedure that will tend to eliminate a possibility of even a 1 per cent permanent disability result in one, a much more satisfied employee, two, less expense to the insurance carrier and three, better work at less expense to the employer.

In the past surgery of the nail has not been extensive. Ingrown nails and paronychia were drained. Lacerated nails were usually permitted to heal as best they might. In the last twenty years there have been only four papers published in American medical literature concerned with surgery of the nails.[1–4] There is only one textbook of surgery that in any way discusses reconstructive surgery of the nail.[5] Reconstructive surgery of the nail may be divided into two groups for the purpose of discussion; first, the immediate repair of the damaged nail and second, delayed or secondary repair of the injured and/or deformed nail.

IMMEDIATE REPAIR

Of the various injuries that might occur to the nail the least severe is a subungueal hematoma following direct pressure on the nail, such as a blow with a blunt object or the squeezing of a finger tip between two hard objects. Most usually the hematoma is small and self-limited; however, the period of disability is lengthened if the presence of the pain factor is prolonged. Early trephine relieves the pressure and eliminates the pain almost instantaneously. Recovery is facilitated, for less separation of the nail plate from the matrix occurs. The nail plate reattaches itself to the matrix much as a split skin graft if the trephine is carried

out early. The patient may return to work immediately with a small pressure dressing over the nail.

Lacerations of the nail may be longitudinal, transverse or one of many oblique types. The oblique lacerations are by

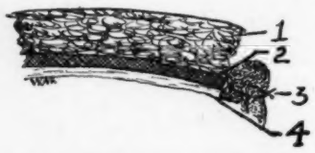


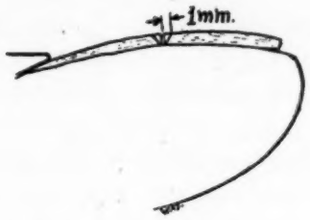
FIG. 1. The pressure dressing of sponge rubber (1) and metal heet (2) on the nail graft (4). The approximation of the skin edge to the edge of the nail graft with mattress suture (3).

far the more common. There is little difference in the procedure of repairing the different types. With the nail that is split longitudinally, frequently there is no injury to the matrix other than a small superficial tear that frequently does not pass through the stratum germinativum. Careful, accurate approximation with sutures after the method of Carter[1,2] insures good results. In this method small holes are bored in pairs near the free border along either side of the split. A fine wire suture is threaded through each pair of holes and tied tightly, so that the split or laceration is thoroughly approximated with two or three interrupted wire sutures. It has been noted that in addition to the above fixation a piece of metal sheet, such as tantalum cut and shaped to fit the nail plate, will maintain vertical approximation much more perfectly. Such perfect approximation will limit the scar formation, which will in turn eliminate nail deformity. The metal sheet protects the nail from injury due to bumps and permits an even pressure to be applied. This will permit the employee to return to work much sooner.

In the transverse and oblique lacerations there is usually other soft tissue injuries. The extent of the débridement governs the reconstructive procedure. In patients in whom little or no débridement is required careful, accurate approximation of the fragments may be instituted. After complete hemostasis has been effected the soft tissues are sutured through the skin only. Deep sutures are not required about the finger tip. The nail fragments should very nearly fall into approximation; however, close approximation can only be insured by suturing the nail plate. This is accomplished by boring small holes in pairs along either border of the laceration. These holes must be exactly opposite one another. They are bored on a slant from a point 1 mm. from the edge of the laceration to a point almost at the edge of the laceration on the under side of the nail plate. In this way the existing matrix is not traumatized. Again a metal plate is fitted to the nail and a small pressure dressing is applied. The sutures are not removed. The free border of the nail is kept closely clipped. The metal plate is worn until the laceration has grown out to the free border. The period required for this growth naturally depends on the site of the laceration. However, the employee can usually continue his work throughout this period.

Avulsions of the nail may be treated in one of three ways. If a distal portion of the nail is lost without extensive matrix damage, a piece of metal sheet is cut and shaped to simulate the lost portion of the nail after the distal end has been cut smooth with a sharp scalpel. The thickness should simulate that of the nail plate. This portion is then bent upon itself so that the remainder of the piece is shaped to fit the whole nail plate. As the nail grows out this plate is pushed ahead. This method is only efficacious in those patients with an avulsion of the small portions of the nail. If the avulsion is extensive with minimal matrix damage, the remaining edge of the nail is straightened by a perpendicular cut with a sharp scalpel. A nail graft is raised from another nail and used to replace the avulsed portion. The procedure of nail grafting is discussed under that subtitle. Occasionally, this procedure will necessitate lost time; however, the lost time will be less than that required for healing without the graft and

the healing will be more perfect. The possibility for infection is decreased. The possibility for permanent deformity is greatly minimized if not completely eliminated. In those patients with an injured matrix a meticulous débridement is effected so that the resulting area is smooth enough to receive the nail graft. Such débridement may, if necessary, be carried down to the extraperiosteal tissue about the distal phalanx. If the new bed is smooth the nail graft will stand an excellent chance of remaining viable.



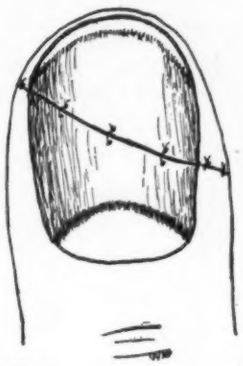


Fig. 2. The suture of the lacerated nail.

The partial amputation, involving the tip of the finger and the nail tissues, may be treated as an amputation by closing the end or as a reconstructive problem by skin and nail grafting. Usually the skin graft is an immediate procedure. The nail graft is effective after the skin graft has taken. At this time the area that was previously the site of the nail bed is prepared for the nail graft. The nail tissues that remain are cut to accept the graft. The skin of the graft is shaved down to the stratum papillosa or about $^{20}/_{1000}$ of an inch of the superficial skin is removed. When a smooth bed has been prepared the nail graft is transplanted as in the procedure of nail grafting to be described.

DELAYED REPAIR

The secondary reconstruction of the nail may be undertaken any time that the tissue of the individual patient seems to be ready to accept this reconstruction. If the initial repair or traumatic treatment falls into the hands of a surgeon acquainted with nail surgery, the need for secondary reconstruction will be limited to those patients with partial amputation, infections and severe avulsed contusions. There are a few complications that occasionally follow the initial reconstruction which will necessitate some minor adjustments. Pterygium of the nail is seen as a sequellae of faulty healing of longitudinal lacerations. The cuticle adheres to the scar tissue and extends distally over the nail in a triangle. The condition may be averted by constantly pushing back the cuticle during the healing process. If the condition is present, an incision is made through the base of the pterygium down to the nail plate at the normal site of the cuticle. The pterygium is then shaved off the nail plate. Bleeding is controlled by pressure. Persistent attention is necessary to maintain the cuticle thereafter until the nail is fully healed. In those patients with a broad nail scar it may be necessary to excise the scar in order to get permanent healing without deformity. The repair of the nail following the excision of the scar follows the technic previously described for the repair of longitudinal lacerations.

Split nails are treated like longitudinal lacerations. If a matrix scar is present it must be excised in order to have a good cosmetic result.

The next most common sequellae of nail trauma is onychauxis. In certain patients the cure of this hypertrophy has been effected by removal of the nail with per-

sistent trimming of the new nail as it grows. However, the more accurate method of nail removal followed by nail grafting[6] facilitates recovery, shortens the period of disability and eliminates permanent disability settlements.

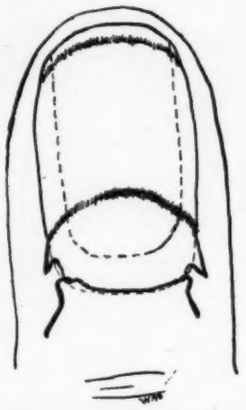


FIG. 3. Nail grafting; the donor nail with the cuticle retracted; the graft is laid out with dotted lines.

Reconstruction of a nail may be undertaken as soon as the other soft tissues of the finger tip are free of infection, have a good blood supply and are free of any devitalized tissue. It is necessary to remove any deformed nail plate. The matrix is preserved as much as possible, particularly the root matrix; however, all scar tissue must be removed before an acceptable bed is prepared for the nail graft. If, in the excision of the scar tissue the viability of portions of the matrix is jeopardized, this matrix tissue must be débrided. The recipient bed must be smooth. The presence of matrix is unnecessary but very helpful as it aids in the maintenance of regular tissue sequence. If the removal of scar tissue demands it, the matrix and reticularis unguis tissue may be excised down to the extraperiosteal connective tissue. The one imperative requirement is that the recipient bed thus formed is smooth, so that the semirigid nail graft will be given complete approximation with the bed at all points. If the lateral nail sulci are not present, tissue folds can be created so that the freshened edge of the skin will fold in to approximate itself with the edge of the nail graft. The graft which has been raised from the donor site is brought over and placed upon the recipient area.

NAIL GRAFTING

The technic of nail grafting[4–6] is not a difficult one. It follows the same principles as split thickness skin grafting; however, because the graft is semirigid certain special conditions must be met. These are a perfectly smooth recipient surface and a definite pressure dressing.

The preparation of the recipient site is described above. The recipient site is prepared when a perfectly smooth bed is consummated, irregardless of what tissue must be sacrificed.

The donor nail is chosen from the finger or toe where the nail most nearly conforms to the original nail. Upon careful observation it will be noted that the nail of each finger and toe is different in convexity, length and breadth. Although it is not essential, it can be readily appreciated that the best nail to use as a donor is the corresponding nail of the opposite extremity. The donor nail is prepared so that the finger and nail are surgically clean. The size of the graft is laid out on the nail. The graft is made as large as possible. A strip of nail about 2 to 3 mm. is left on the lateral aspects in order to maintain the width of the nail as the new nail grows and to prevent the formation of an ingrown nail. As nails do vary in thickness the suggested width is arbitrary. Enough nail plate should be left so that it will be strong enough to lend the desired support. The proximal end of the graft should reach proximal to a little more than half of the lunular nail plate. The graft is freed from the matrix by dissection and transferred to the recipient site. It is imperative that the recipient site is dry. The coagulum contact method of graft adhesion is employed. Redisolved commercial plasma and thrombin is used with success. The skin edges are brought in contact with the graft. If a new bed has been made or a loss of sulcus wall

is present, the skin edges are rolled underneath themselves to form a new sulcus. This is maintained by mattress sutures. (Fig. 1.) The graft is supported with a covering of tantalum sheet (0.0025 of an inch) that is cut and shaped to exactly fit the graft. Pressure is applied to the graft through the tantalum sheet with a sponge rubber pad and bandage. (Fig. 1.) The sponge rubber pad is cut to fit the graft. The thickness should be about ¼ of an inch. The donor area is dressed with a similar dressing.

The postoperative care simulates that for skin grafting. The dressing is changed on the tenth day unless a morbid aroma arises suggesting death of the graft. The dressing is changed immediately if there is any evidence of drainage. A pressure dressing should be maintained over both recipient and donor areas for approximately one month. However, if the nail requires further protection the dressing should be continued. Occasionally, small outgrowths of granulation tissue appear about the periphery of the nail graft. This will occur if the skin edge and graft edge have not been accurately approximated. The outgrowth is cauterized with a silver nitrate stick. After the nail grows out it should be trimmed short at its free border with a very sharp scissors or nail clip without applying pressure on the nail plate.

The scientific explanation for the advantages gained by the use of the tantalum sheet in many of the described procedures is a bit obscured. However, it has been found that its use facilitates the more normal regeneration of the nail plate. Probably it acts as a trellis to direct the growth. In some patients an early tendency to hypertrophy will be noted. A very mild dose of *x*-ray will tend to curb this excessive growth. A course of six very light treatments are usually used with the radiosensitiveness of the matrix tissue borne in mind.

It is believed that with these few technics added to the armamentarium of the industrial surgeon that a distinct percentage of permanent settlements may be erased.

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INJURIES TO THE ABDOMEN IN INDUSTRY*

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IT is fortunate that with improved safety precautions and education injuries are less frequent in industry than a decade or two ago. The nature and extent of surface injuries or injuries to the extremities are usually obvious; those involving the abdominal viscera are less likely to be recognized early.

In discussing abdominal injuries the nature of the etiologic factor plays a major rôle in formulating our plan of treatment and aiding us in diagnosing the extent of probably intra-abdominal injury. Therefore, the exact history of the nature of the injury is highly important. In evaluating an injury of the abdomen one should inquire into the past medial history to determine if any pre-existing intra-abdominal lesion could play a part in the present clinical picture. This is especially important from the medicolegal standpoint as it may have bearing on the compensability of the alleged accident, not for the immediate period alone but for the future as well.

Cutting or tearing injuries of the abdomen are rare in industry and usually involve only the adbominal wall. Heavy moving objects or crushing objects are the most common etiologic causes of intra-abdominal injuries. Penetration of the abdominal cavity by small or cutting missiles, while not common in industry, require mention because often what appears to be an insignificant surface lesion may involve the viscera. Probing or examination of the wound is of no value in determining the depth of the wound if the wound extends to or below the superficial fascia of the abdominal wall, since the mobility of the various muscles and fascia layers does not permit following the course of the missile. There is but one way to be sure that the peritoneum has not been penetrated and that is to inspect it which requires that it be exposed surgically.

Occasionally, due to strenuous exercise there may be hemorrhagic infiltration of the abdominal wall without any direct trauma. This was seen during the training maneuvers of World War II and simulated acute appendicitis. Fruin and McLaughlin reported on fifty-one patients, 96 per cent of whom were affected in the lower portion of the rectus muscle. Ten of these patients had palpable hematomas on admission to the hospital. Since 86 per cent affected the right side appendicitis was easily confused with the cause and interpretation of the symptoms and findings. Treatment of this type of injury consists of rest and the hematoma and soreness will subside rapidly.

Because of the mobility of most of the abdominal viscera, trauma applied slowly is less likely to cause rupture of a viscus than are sharp sudden blows. A distended hollow viscus is more likely to rupture than one that is empty, while a hollow viscus which is the site of a pathologic process such as an ulcer or a diverticulum might be expected to rupture easily. Such a locus of a rupture is actually rare and nearly all patients with a ruptured hollow viscus whom we have seen have had ruptures through normal appearing structures. All intra-abdominal hollow viscera are not intraperitoneal and this might cause some confusion in diagnosis if not properly considered. Notably, the duodenum, the ascending colon, the descending colon and the bladder are extraperitoneal. Not only are these structures extraperitoneal but they are relatively fixed structures and do not move freely when force is applied.

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The root of the mesentery of the small bowel is also relatively fixed and is likely to be bruised from crushing injuries. Solid viscera, the liver, spleen, pancreas and kidney are moderately fixed structures but have sufficient mobility and compressibility that fairly well tolerate slowly applied pressures. The application of pressure applied suddenly is more apt to cause rupture of these structures, especially if they are enlarged, than an even greater pressure applied gradually. The viscera of young people appear to stand trauma better than in the older age group.

The diagnosis of serious damage to intra-abdominal structures is not usually possible immediately after the accident. The effects of a severe blow to the abdomen usually causes a great deal of disturbance immediately and soreness in the abdomen is likely to persist for some time even when no serious intra-abdominal injury is present.

The fact that the patient appears to recover quickly from a severe blow to the abdomen does not rule out a serious intra-abdominal injury, since quite often the patient will appear to recover from the immediate effects of trauma to the abdomen but will develop signs of visceral injury later. The following is an illustrative case report.

CASE REPORTS

Case 1. L. J., aged forty-five, a maintenance man, was engaged in sawing a piece of wood which caught in the blade and was thrown against his abdominal wall. At first, he did not think he was hurt but soon he became nauseous and noticed severe pain about the genitals and rectum with pain later in the abdomen. He was admitted to the hospital five hours after the accident. The physical examination showed no surface evidence of trauma but the abdominal wall was rigid. An operation seven and one-half hours after the accident showed a tearing of the ileum.

Accordingly, such a patient should be kept under observation or advised to report immediately after the first evidence of abdominal pain or nausea, weakness or shortness of breath on exertion. It is not unusual for a ruptured hollow viscus to result in delayed signs or symptoms for several hours. Those from ruptured solid viscera may be delayed for days or weeks.

Following injury to the abdomen the development of rigidity or acute tenderness is an indication for exploratory laparotomy if other signs or symptoms support the diagnosis of a ruptured viscus. The *x*-ray is an important adjunct to diagnosis. In all instances a supine and upright flat film which includes the diaphragm are essential.

Two important conditions for which operation is not indicated at this point, which may simulate a ruptured viscus so far as signs and symptoms are concerned, may be definitely diagnosed by the *x*-ray. These are ileus and acute gastric dilation. The latter usually follows immediately after the injury and may persist for some time; the former usually occurs some hours after the injury. Acute gastric dilatation is easily recognized by *x*-ray, the supine film revealing a large gas shadow outlining the stomach, the upright film is a fluid level. In patients with severe prostration, cyanosis, abdominal pain and tenderness, increased pulse rate and decreased blood pressure may be present and can simulate a severe abdominal lesion. Those patients with milder degrees may be associated with no more than abdominal discomfort and nausea. The treatment is obvious decompression by means of a nasal catheter and reassurance of the patient is usually all that is required. Ileus, frequently an associated condition in retroperitoneal injuries, is best treated by intestinal intubation and suction drainage.

In those patients with a ruptured hollow viscus the most common sites are the jejunum, duodenum and colon. Rupture of the bladder is not uncommon in association with fractures of the pelvis and the tear in the bladder is usually extraperitoneal. It is strange that the cecum which usually contains a fair amount of gas is so infrequently ruptured. The colon which is so commonly the site of diverticuli

and usually contains gas might be expected to be more frequently ruptured. That is probably due to its large capacity which permits a freer movement of the gas.

X-ray findings in rupture of the intestinal tract are diagnostic early in more than half the patients; later, almost all will show some gas beneath the diaphragm if the tear is intraperitoneal and of any size. The fact that there is air beneath the diaphragm gives one no indication as to which portion of the gastrointestinal tract is involved. The finding of diffuse scattering of air in the retroperitoneal tissues is much more helpful in localizing the site of a ruptured hollow viscus. In rupture of the duodenum this is a dependable localizing sign. Fine diffuse mottling of gas in the subhepatic area or along the psoas line, especially on the right side, is quite unlikely to come from any place but the duodenum. This retroperitoneal extension of gas may be so extensive that it actually reaches the pelvis and the flat film may show a foamy appearing line from the area of the duodenum to the pelvic brim or lower; when it is present the film is diagnostic. The following case report illustrates such a condition.

Case II. A. S., a twenty-seven year old black male, an employee of a concrete company, fell one story and the air-hammer which he had been using fell on his abdomen. Initial *x*-rays were not diagnostic. Films made a few hours later, however, revealed definite, large numbers of small vesicles of air in the retroperitoneal space as has been described. An exploratory operation was performed and the duodenum was found almost completely divided at the junction of the second and third portions. The duodenum was repaired and the patient made an excellent recovery.

In our experience rupture of the jejunum is not uncommon. One might expect to find the rupture near the fixed portion of the jejunum but in our series this was not always the case. Usually, however, the tear is found in the first 2 feet of the jejunum. The following case is illustrative.

Case III. J. W., aged twenty-seven, a pattern worker, was struck in the abdomen by a board about 10 A.M. and reported to the plant hospital. The pain was not severe so he returned to his home whereupon, he noticed some pain in his abdomen when he drank some broth; this was vomited almost immediately. He was admitted to the hospital about six hours after the accident. The physical examination showed a well nourished white male, with an anxious look on his face. His respirations were rapid. The abdomen was board-like and extreme pain was apparent on the slightest pressure. At the site of a slight abrasion to the left and below the umbilicus the pain and tenderness was more intense. The abdomen was tympanitic and the liver dullness partially obliterated. At operation ten hours after the accident, free brownish fluid resembling broth escaped from the peritoneal cavity and the presenting segments of the distended small intestine showed a plastic exudate. The point of laceration was about 1 foot distal to the ligament of Trietz and was large enough to admit the little finger. It was repaired with interrupted plain and fine chromic catgut sutures fixing the omentum at the site of repair.

While rupture of any hollow viscus is likely to result in peritonitis, those tears found in the large bowel are particularly hazardous and require early laparotomy. While this is what one would expect, it is worthwhile to point out that we have seen several patients in whom gas escaped into the peritoneal cavity from a small opening in the colon, which caused a massive right subdiaphragmatic collection of gas and only a localized well walled-off abscess resulted.

The solid viscera most commonly injured in trauma to the abdomen are the liver and spleen. The result of rupture of either of these structures is that of severe loss of blood. Smaller tears in the liver may result in but a small loss of blood before clotting occurs. This is not usually so in a patient with splenic rupture. Even small tears in the spleen may continue to ooze blood over a long period, so that the first outstanding feature which calls attention to the seriousness of the injury is severe anemia. Larger tears are more likely to present the picture of acute blood loss. We have had little suc-

cess in repairing such rents and find it far simpler to remove the traumatized spleen. Massive tears in the liver likewise result in acute blood loss. In such patients suture of the rent is usually possible, especially with oxidized cellulose or gelatine foam as supports for the suture to aid in the prevention of tearing, as well as the use of these substances in conjunction with thrombin to control bleeding. In massive tears of the liver the possibility of bile peritonitis is a threat and in those patients in whom there is any question of poor approximation of the torn liver it is wise to drain. It is rarely necessary to pack the rent in the liver with massive gauze packing as the absorbable material is more effective and simpler to use.

Traumatic peritonitis can result when there is no wound in the abdominal wall and the peritonitis is free from bacterial contamination. The solid organs are more likely to be injured from a blow than the hollow organs. If the bladder is injured with leakage of urine into the peritoneal cavity, a severe peritonitis results. Bile leaking, likewise causes a severe peritoneal reaction. Blood in the peritoneal cavity may be absorbed and cause little reaction but if it clots and the fibrin holds the cells, peritoneal adhesions usually result.

Rupture of the pancreas is quite likely to be overlooked and small tears may result in a cyst formation, to be discovered at some time remote from the accident. The head of the pancreas or that portion lying over the spine is most likely to suffer from crushing injuries. It is in this portion that the ducts are larger and may actually result in great losses of pancreatic juice, especially following drainage of a resulting abscess. The following is an illustrative case.

Case IV. B. M., a forty-one year old white male, was admitted to the hospital July 11, 1946, thirty minutes after being crushed between the back of a truck and a loading platform. On admission the patient was in severe pain but had no shock. Immediate *x*-rays revealed free peritoneal air, fractured transverse lumbar processes and one spinous process of a lumbar vertebra. The patient also had bilateral fractured acetabulae and separation of the right sacroiliac joint. Immediate exploration under general anesthesia revealed a stomach which had been sectioned at the pylorus. The pancreas was bleeding freely and there was a large rent in the mesentery and the ligament of Treitz. A subtotal gastric resection was performed. The pancreas was packed with oxycel gauze and the mesentery of the small bowel repaired. The patient made an excellent recovery, being discharged in fifteen days. He was back at work in five months.

Rupture of the receptaculum chyli is not a common injury. Usually following this injury there is severe upper abdominal pain and pain in the back. The lesser peritoneal sac may become markedly distended with lymph, and if this is drained, the lymph may drain to such an extent and for such a time that it will cause serious problems in water balance and nutrition. It is difficult to find the opening in the lymph channels. When possible to find the lymph seeping through a rent, it usually suffices to close the surrounding tissues over the area. As a rule, however, packing the area until scar can form to close the defect is the best that one can do.

CONCLUSIONS

Intra-abdominal lesions resulting from industrial accidents are serious problems. The recognition of such lesions is not always easy. Unless the patient is carefully observed with signs and symptoms properly evaluated, the true nature of the intra-abdominal lesion may be overlooked.

It is important in every injury to a patient involving the abdomen, to obtain a careful history and physical examination and the circumstances concerning the accident should be accurately recorded, since in many instances intra-abdominal lesions may develop subsequent problems, not only of a medical nature but of a legal nature as well.

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INJURIES INVOLVING THE GENITOURINARY TRACT*

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SINCE cessation of hostilities in World War II, several reports have appeared regarding war injuries to the genitourinary tract. Most of these articles have appeared in the Journal of Urology. Barring penetrating wounds (gun shot and shell fragments) and lacerations of the external genitals due to land mines, etc., it would seem that there is little difference in the management of the injuries to the genitourinary tract in civil and military practice.

In industry injuries to the genitourinary tract are relatively uncommon and will be considered under the following headings: (1) Lacerations of the external genitals, (2) prostatitis and epididimitis following general body trauma, such as falls, blows, etc., (3) lacerations of the urethra—pendulous, bulbous or prostatic, (4) bladder and (5) kidney.

Laceration of the External Genitals. These lacerations have been extremely rare. It is very important to save all penile and scrotal skin and do a minimum amount of débridement as the regenerative powers of this skin is very great. In the end results this is seen in the urinary extravasation when large amounts of scrotal and penile skin have been destroyed.

CASE REPORTS

An airdrill tangled in a patient's trouser leg and tore off most of the scrotal and penile skin, leaving the testicles hanging free with the blood supply undamaged. The testicles were buried in the perineum and covered with the remaining scrotal skin. The skin of the thighs was stitched together in the midline and the prepuce was stitched back to the skin of the abdomen at the root of the penis. The wound healed mostly by first intention. At the end of three months there had been sufficient regeneration and stretching of the penile and scrotal skin to produce almost a new scrotum. The anticipated plastic to construct a new scrotum was unnecessary.

In the case of another patient a cylinder head explosion caused hematoma of the penis resulting in impotence. A cylinder head compressor blew off and just "dusted" across the anterior surface of the abdomen and thighs. There was a slight laceration of the prepuce and hemorrhage into the corpora. The end result was several indurated areas in the shaft of the penis resembling Peyronie's disease as well as impotence.

Strains Due to Slipping. Direct trauma to the scrotum and lower abdomen are often followed in a few to twenty-four or thirty-six hours by frequency, hematuria and scrotal swelling (epididimitis). These usually resolve under rest in bed and chemotheraphy. The epididimitis is often resistant and disability is usually shortened by an epididimectomy. Almost invariably in these patients there is pus in the prostatic secretions. There may be no urinary symptoms. Usually there is pain in the groin preceding the scrotal swelling, the inference being that the trauma lights up a pre-existing prostatic infection which extends down the Vas involving the epididymis.

Laceration of the Uretbra. Laceration of the *pendulous urethra* is rare and has been seen only in knife wounds or fracture of the penis in erection.[2]

Bulbo-membranous lacerations are straddle or "crotch" injuries due to falling astride a beam, one leg down an opening (manhole[3] or loading dock), a wrench handle blow to the perineum, etc. Figure 1 shows the triangular ligament and the fascias which determine the direction of the

* All cases are the writer's private cases unless otherwise mentioned.

extravasation following the laceration of the bulbous urethra. Free bleeding from the meatus independent of urination is the presenting sympton. There may or may not be acute retention of urine and there may be extravasation into the tissues with very

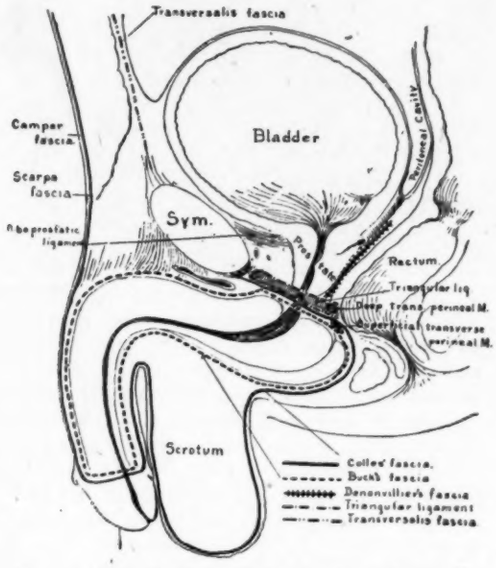

Fig. 1. The fasciae of the penis and scrotum are important as they control the direction of the extravasation of urine. Particular attention is directed to the triangular ligament (after Wesson[1]).

little bulging. (Fig. 2.) In management, first try to pass a fair sized soft, rubber catheter, No. 20 or 22 double eye or a Foley catheter; if successful, tie in. This serves as an internal splint and should remain *in situ* for five to ten days. If unsuccessful, gently try a No. 24, a 26 F sound or a catheter on a stilet. This may "iron out" the ragged edges and permit the passage of a soft rubber catheter. Do not use small, rigid instruments as they catch in small pockets. Do not spend much time "poking" around in an effort to pass the obstruction, thereby, increasing laceration and spreading infection. Do not wait a few days and try again as strictures form rapidly and soon become filiform requiring treatment and often operation. If still unsuccessful, perform a suprapubic cystotomy and try Davis[4] interlocking sounds or a retrograde catheter. (Fig. 3.) If unsuccessful and the condition of the patient

Fig. 2. Urethrogram in a "crotch" trauma; suprapubic cystotomy. Davis interlocking sounds are not successful. The catheter is passed retrograde and a second catheter is attached to it and drawn back into the bladder. Later a peritoneal hematoma was evacuated.

warrants, put him in a lithotomy position and do a perineal section on the beak of a sound or Wheelhouse staff, (Gibson[5]) pick up the retrograde catheter and thread a catheter through the urethra into the bladder. Close the perineum loosely and drain suprapubically for a few days. Leave the inlying catheter ten to fifteen days. If the patient's condition is such that perineal section should not be attempted in addition to cystotomy, go back in two or three days or as soon as his condition warrants, trying a retrograde first and then a perineal section. Continuity of the urethra must be established and now is the time to do it. If postponed it is necessary to excise the scar and probably do a plastic. (MacGowan,[6] Cabot[7] and McLean and Gerrie.[8]) Postoperative sounds are necessary indefinitely because if neglected almost certain formation of stricture will arise.

Injuries involving the *prostatic urethra* and tearing off of the prostate at the apex, or lacerations through the prostate almost invariably are the result of injuries with

fractures to the pelvis. (Fig. 4.) There is usually shock, bleeding from the urethra and urinary retention. There is a tenderness and some fullness in the suprapubic area and within a few hours following injury there is considerable ileus present. Catheterization is impossible or misleading, (Fig. 6) the catheter passing into a perivesicle pocket. It may drain urine at first but infection sets in shortly. This type of drainage should not be attempted. Appropriate treatment of the shock if present should be carried out, following which *x*-rays of the pelvis should be made. A soft rubber catheter may be passed and a contrast medium injected. Figure 5 shows the extent of extravasation. This is probably unnecessary as the diagnosis of ruptured urethra has already been established. Suprapubic cystotomy should be done as soon as the patient's condition permits. Following the skin incision it is often noted that the subcutaneous fat and muscle are infiltrated with blood due to the trauma, and on separating the muscles the perivesicle space will be found to contain varying amounts of blood and urine. Land marks are often obliterated. If after opening the bladder, Davis interlocking sounds do not work or are not available, a pair of ordinary sounds, (e.g., No. 24 and 25 F) may be tried. If these fail a catheter on a stilet may be tried. With a finger in the internal meatus the catheter may be guided into the prostatic urethra. (Fig. 7.) This, in the author's own experience, has been by

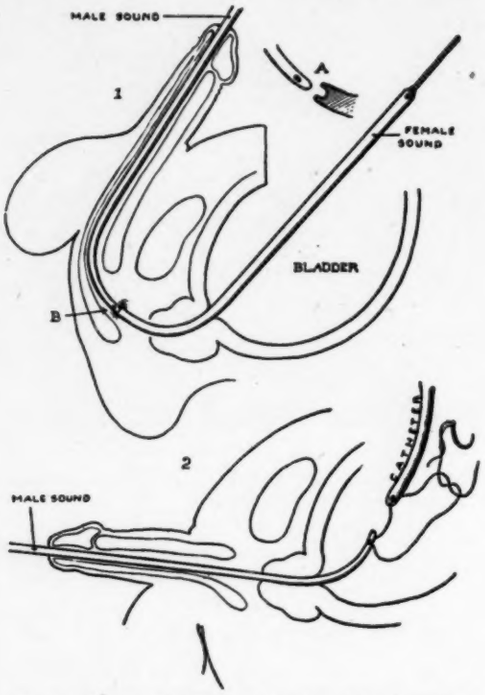

FIG. 3. From Davis's original article describing interlocking sounds for use in ruptured urehtras.[4] No. 1 shows male sound introduced via meatus of the penis to the site of rupture of the urethra, B, and engaged in the cupped end of the female sound introduced via the bladder. A demonstrates the cupped end of female sound and tip of male sound with a hole in it. No. 2 is the male sound with a suture through hole at tip which is ready to pull the catheter from the bladder through the penis.

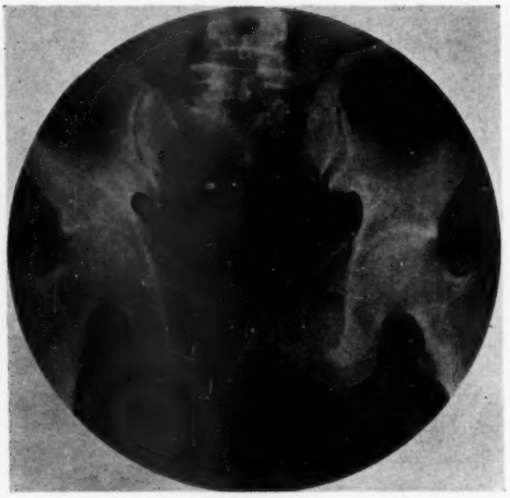

FIG. 4. Fractured pelvis with crushing injury. The patient was crushed between bumpers of two railroad cars. This is a type of pelvic fracture producing varying degrees of laceration of prostatic urethra with extraperitoneal extravasation of urine and hematoma, as shown in Figures 5 and 6. The displaced fragment produces a shearing or tearing (partial or complete) of the prostatic urethra. A urethral catheter drained blood and urine. At operation the tip of the catheter was found in a perivesicle pocket, having passed out through the laceration in the prostatic urethra. About five days after injury with inlying catheter and suprapubic drain both in place, extensive extravasation took place over night so that it was necessary to incise both thighs widely in the region of Scarpa's triangle. Following incision and drainage the patient made an uninterrupted recovery. The suprapubic drain was removed in three weeks. A week later the suprapubic sinus was healed solid and the inlying catheter was removed.

far the most successful procedure. If there is a wide separation of the distal and proximal ends of the severed urethra (Fig. 5), they may be drawn together by replacing the inlying catheter with a Hagner bag (Ormund and Cathran[11]), or as recently described by VerMooten,[10] using a Foley catheter. There may be sufficient shifting of the bony fragments of the pelvis to interfere with an inlying catheter and cause an acute angulation of the urethra after removal of the catheter. In this case the projecting bone fragments must be removed. Repair may be done through the perineum (Young[12]). Adequate drainage should be provided and this may be carried out through counter openings in the perineum. The inlying catheter should remain *in situ* fifteen to twenty days. Sounds should be passed at increasingly longer intervals until the patient can go three to six months without contraction of the stricture. They should be sounded at regular intervals for years afterward, if not for the remainder of their lives.

Fig. 5. Schematic representation of extreme degree of extravasation following rupture of urethra posterior to triangular ligament. This illustration shows why an inlying catheter may drain urine but still not drain the bladder and demonstrates the necessity of suprapubic cystotomy. It also shows the necessity of perineal drainage. This same type of extravasation may occur in extraperitoneal ruptures of the bladder. VerMooten[10] maintains that the separation and the floating up into the abdomen of the bladder and prostate leaves a palpable doughy area. This is palpable by rectum.

A high percentage of these patients are impotent following the injuries, whether due to damage to the blood or damage to the nerve supply to the penis is not established. This is of great importance from a medicolegal standpoint in regard to traumatic neurosis and neuropsychiatric disturbances.

Considerable stress has been placed on the necessity for prolonged follow-up procedures of these patients. Traumatic strictures contract much more rapidly than inflammatory (gonorrheal) strictures.

Rupture of the Bladder. This is relatively an uncommon injury, due largely to the fact that the bladder is placed deeply in the pelvis where it is inaccessible to trauma except in the most severe crushing injuries or fracture of the pelvis with penetration by a fragment of bone. The author has seen three or four patients from the field of industry. The writer reported on twelve patients from the Receiving Hospital of Detroit (Rexford[13]). In the series referred to, mortality occurred in patients who had complications of multiple fractures, long bones and the skull. In a four-year period ending July 1, 1940, there were twelve patients in 83,500 hospital admissions. Dr. I. K. Bacon[14] reported on 147 ruptured bladders over a ten-year period with 488,000 admissions at the Los Angeles City General Hospital, which was about three times the incidence of occurrence in the above mentioned series.

These injuries were incurred in falls, automobile accidents and brawls, the majority having been more or less intoxicated. The conclusion is that it is almost impossible to rupture an empty bladder but that a full bladder may rupture fairly easily.

There is retention or slight dribbling of bloody urine, shock, rigid abdomen or pain and tenderness just above the symphysis. Catheterization may show a small amount of bloody urine or none at all, the urine draining back into the peritoneum. Cystoscopy is uncertain owing to the inability to distend a leaking bladder. In the author's

experience the cystogram makes the diagnosis, (Figs. 8 and 9) using either 15 per cent sodium iodide or a one-quarter strength skiodan solution as a contrast medium.

Treatment is immediate operation or as soon as the patient's condition permits. Delay is dangerous leading to peritonitis or perivesicle suppuration depending on the location of the tear—intra- or extraperitoneal.

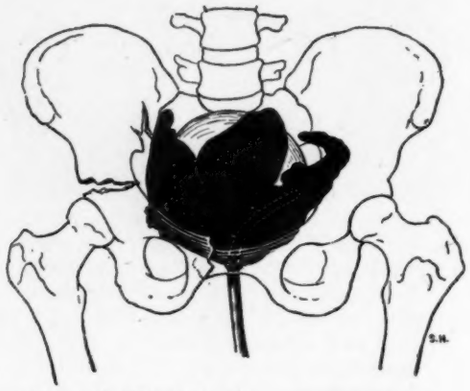

Fig. 6. Showing the anteroposterior view of Figure 5 and the catheter passing through the laceration in the urethra.

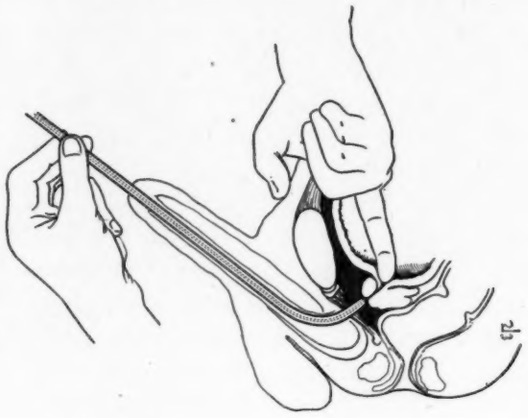

Fig. 7. Laceration of the urethra at apex of prostate; suprapubic cystotomy. The catheter on a flexible stilet is guided into the prostatic urethra by the operator's finger in the internal meatus.

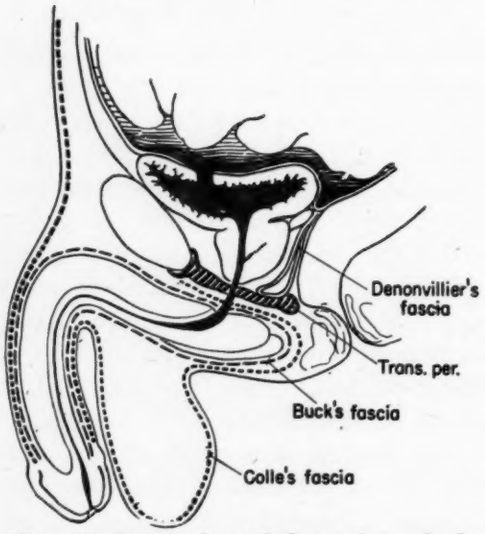

Fig. 8. Intraperitoneal laceration of the bladder with extravasation of urine into the peritoneal cavity shows futility of trying to find the opening with a cystoscope. The bladder collapses about the beak of the scope.

The repair may be done transvesically or through the abdomen, the latter being safer as it provides an opportunity to inspect the abdominal contents for injury. It is probably safer to drain the bladder suprapubically, although if the injury is recent a primary closure with a catheter drainage may be considered. If the rupture is extraperitoneal and of much duration, the perivesicle space should be well drained. Penicillin and the sulfonamides should be used freely. If primary closure is done, ten to fifteen days of catheter drainage should be ample to allow solid healing. If drained suprapubically, the suprapubic tube may be removed after five to six days and an inlying urethral catheter substituted until the suprapubic wound is dry. The necessity for immediate surgery cannot be emphasized too strongly.

In those patients with uncomplicated cases operate early and the mortality should be slight. The mortality varies inversely with the interval between injury and surgery.

Kidney. In spite of the fact that the kidney is tucked away in a rather inaccessible position, protected by the ribs, spine and abdominal muscles and cushioned in its fatty capsule which acts as a sort of shock absorber, injuries to it have not been uncommon; e.g., in a four-year period ending

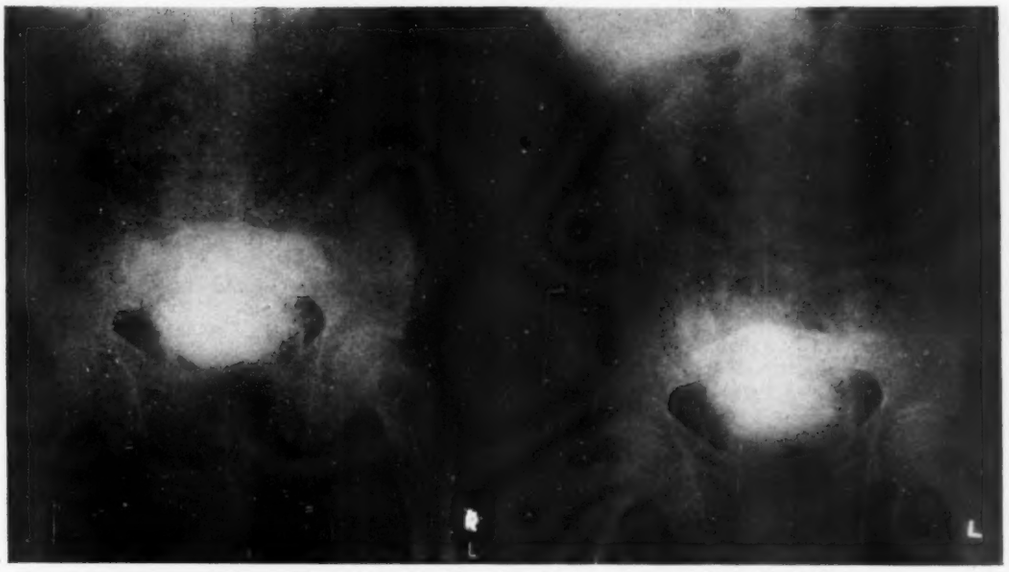

Fig. 9. Cystogram in laceration of the bladder showing contrast medium in abdomen; suprapubic cystotomy. The tear is 2 cm. back of the peritoneal reflection off the bladder. The peritoneum is pushed back and closed without drainage. The bladder closed about a suprapubic drain and the laceration closed as an extraperitoneal laceration. Note extravasation of urine into peritoneal cavity. Cystoscopy was without value as the bladder collapsed about the beak of scope.

July 1, 1940, at the City of Detroit Receiving Hospital on the urology services of Drs. Keane, Plaggemeyer and the writer,[13] there were 126 patients who were classified as having trauma to the genitourinary tract. Of these, fifty-eight were kidney injuries. The degree of injury varied from slight contusion with pinkish urine to gross hematuria with a complete shattering of the kidney or damage to the blood supply in a crushing injury with complete infarction of the kidney (Rexford[15]). (Fig. 13.)

Of the fifty-eight patients, forty-seven were not operated upon but were treated conservatively and they recovered; seven were operated upon with one death; three were released to other hospitals and one was not operated upon but died of shock.

All patients with cases of trauma should have an immediate urinary examination. If unable to void they should be catheterized. If there is bleeding there is very likely to be a kidney injury or a slight laceration of the bladder mucosa present. Most of these patients are treated expectantly with rest in bed, the hematuria subsiding. If this does not occur the patient should be cystoscoped and a retrograde pyelogram made. This will show the extent of the damage and determine whether bed rest

Fig. 10. Kidney trauma following a fall. A tear occurred into the cortex but not through the fibrous capsule. Contrast medium does not pass into the perirenal tissues. Rest in bed was followed by recovery.

Fig. 11. Retrograde pyelogram showing contrast medium extravasating into perirenal tissues. The patient fell a few feet and a companion fell on top of him. He came into the hospital in shock, with grossly bloody urine, pain and rigidity in the upper left quadrant. On the following day an intravenous pyelogram showed no dye in the left side; on the next day a retrograde pyelogram showed the lower and middle calices filling, the dye passing out into the perirenal tissue. The patient's temperature had gone up and he did not present a good appearance. Immediate nephrectomy was done and the patient's condition improved and he looked fine. In this case, the upper third of the kidney was completely broken off and repair of the remaining portion was not feasible because of the damage to the blood supply. Recovery followed operation.

Fig. 12. Illustration of kidney showing impossibility of repair. An explosion threw the patient against a 2 by 4 railing, striking him in the left loin. He was brought into the hospital in shock. His blood pressure was 60/40. A blood transfusion was given the following day. The blood pressure rose to 120/70, but there was gross hematuria and marked ileus. An intravenous pyelogram showed the right kidney only. Hematuria persisted and on the following day the kidney was removed. It was completely broken in two. There was a large tear through the larger portion of the kidney and a large perirenal hematoma. Recovery followed removal.

or surgery is indicated. (Figs. 10, 11 and 12.)

Intravenous pyelography has not been too satisfactory. A contused kidney often has its function temporarily delayed. The amount of abdominal distention occurring in these obscures the pyelogram if obtained and does not begin to give the information that cystoscopy and retrograde pyelography does.

The kidney has great recuperative powers as witnessed by the fact that it may be split from pole to pole for the removal of a calculus or the mauling it receives from the prolonged search for an elusive stone, either through a nephrotomy or a pyelotomy incision. In a few weeks these kidneys show a normal function and pyelogram.

In industry the chief causes of kidney injuries have been falls and blows to the abdomen. Usually there is little or no external evidence of injury.

It has been the writer's experience that the larger proportion of the patients with kidney injuries get well when treated conservatively and that about one out of six require surgery. The surgery in this case

Fig. 13. Infarction of kidney in crushing injury. The man was crushed between a pillar and a moving crane. There was shock but no hematuria. A retrograde pyelogram was normal. There was no function or urine excretion at the end of 45 minutes. Nephrectomy. Huge infarcts of the kidney. Recovery prolonged because of damage to the tail of the pancreas and drainage of pancreatic fluid.

is nephrectomy. The author has never seen a kidney at operation that was amenable to repair; all were so badly broken or shattered that the only recourse was removal. The "does" and "don'ts" for traumatic kidneys are: Do not hastely rush into surgery; do not place much reliance on intravenous pyelograms and do have a cystoscopic examination and retrograde pyelogram made as soon as the patient's condition permits.

The management of traumatic kidneys have some time been described as "masterly neglect."

CONCLUSIONS

All injured patients who do not void a clear urine in a comparatively short time should be catheterized on the off chance that there may be some damage to the urinary tract. In other words, a urinary examination must be done on all patients.

All injuries involving the urinary tract should be investigated with a catheter: (1) If the catheter is obstructed, there is damage to the urethra at the point of obstruction. An urethrogram will show the amount of extravasation; (2) If the catheter passes, inject contrast medium and have *x*-rays made. This may show: (*a*) A passage of the contrast medium into the peritoneum if an intraperitoneal rupture is present (Figs. 8 and 9); (*b*) passage of the contrast medium into the perivesicle region. This may be due to either an extraperitoneal rupture of the bladder or a tear through the prostate or urethra, posterior to the triangular ligament and (*c*) a normal cystogram with bloody urine.

If conditions (1) or (2*a*) or (2*b*) are

present immediate surgery is indicated. Delay means extravasation of urine and infection, necessitating multiple incisions and prolonged convalescence. If condition (2c) is found there may be a slight laceration of the bladder mucosa or varying degrees of kidney damage. Here, one may delay. An intravenous urographic study and cystoscopy with retrograde pyelograms should be carried out as soon as the patient's condition warrants. The majority of these patients get well with rest in bed.

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DIAGNOSIS AND MANAGEMENT OF PERIPHERAL NERVE INJURY*

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DYSFUNCTION of a peripheral nerve may occur from contusion and laceration in wounds, in association with fracture and dislocation of long bones and in some instances by chronic irritation. By far the most common type of interruption is that due to involvement in lacerations, bullet and other penetrating wounds. This paper will deal primarily with the diagnosis and management of nerve injury in lacerations. A few comments will also be made concerning involvement in dislocation and fracture of long bones and from chronic irritation.

NERVE INJURY IN LACERATIONS, BULLET AND OTHER PENETRATING WOUNDS

In civilian practice the most common site of involvement is at the wrist and the forearm. Fully 60 per cent of the patients we have had in our group belong in this category. The incidence in penetrating wounds of World War II shows that the upper extremity was involved in 70 per cent of the patients and the lower in 30 per cent.[1] The ulnar nerve was most commonly injured (32 per cent of the total). The median nerve accounted for 19.5 per cent; the radial 14.1 per cent; the sciatic 16.9 per cent and the peroneal 7.9 per cent; all others were less than 3.6 per cent (tibial etc.). In Table I the nerves involved in 174 civilian patients with nerve section are given.

TABLE I

Face	
Facial nerve	7
Upper Limb	
Wrist	
Median	42
Ulnar	30
Median and ulnar	16
Forearm	
Median	4
Ulnar	13
Radial	6
Mixed	5
Arm	
Median	6
Ulnar	8
Radial	14
Mixed	10
Axilla	
Brachial plexus	8
Lower Limb	
Femoral	1
Sciatic	4
Peroneal	7

DIAGNOSIS

The diagnosis of a nerve interruption is usually simple. Mistakes are frequently caused by an oversight of the possibility of nerve involvement. In many instances a few questions and answers clinch the diagnosis. The location of the laceration should suggest to the examiner the possibility of nerve involvement. A laceration in the middle of the palm-wrist junction may be associated with section of the median nerve. A more medial laceration may involve the ulnar nerve. An extensive laceration of the wrist often involves both ulnar and median nerves. A relatively superficial laceration over the epicondylar groove on the medial aspect of the arm may involve the ulnar. The radial nerve may be sectioned by a laceration on the anterolateral aspect and below the middle third of the arm. A laceration on the lateral aspect of the head of the fibula can result in section of the peroneal nerve. The location of the laceration alone should, therefore, suggest possible nerve involvement.

The cardinal neurologic features of either anatomic or physiologic nerve interruption

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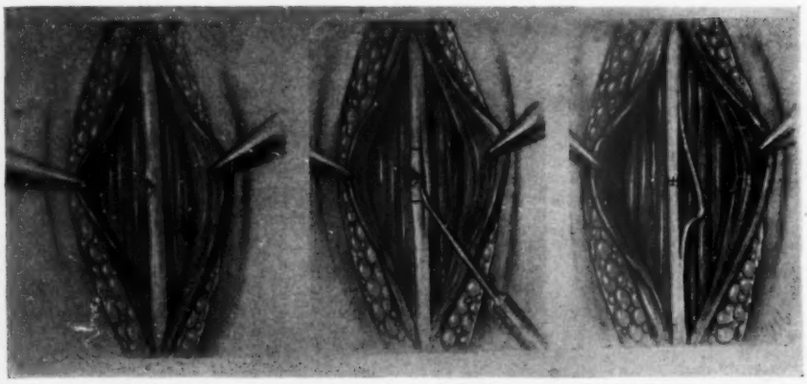

FIG. 1. Partial section of a nerve and operative management. The uncut portion is carefully separated from the cut portion. The ends of the cut portion are sutured after débridement.

include sensory changes, motor loss and sudomotor paralysis. In some nerves the sensory defect is most prominent while in others it is the motor and in still others, both motor and sensory involvement are quite marked. There is usually sudomotor paralysis in the area of anesthesia in extremity nerve section. A more refined, objective and practical method of evaluating zones of nerve interruptions is by means of measuring the changes in electrical skin resistance.[2] In the denervated skin area there is an absence or decrease in sweating with consequent increase of the electrical resistance. By means of the dermometer an involved area can be accurately plotted. This method does not depend upon the subjective responses of the patient.[3]

A few simple points suffice to diagnose accurately a given nerve lesion. In the next few paragraphs these will be described.

Diagnosis of Nerve Lesions:

Median nerve section may be identified by the presence of sensory loss in the lateral three and one-half fingers and the corresponding portion of the palm. These patients also have anesthesia of the distal two phalanges of the index, long and one-half of the ring finger on the dorsal surface. Such a sensory pattern often clinches the diagnosis of median nerve dysfunction. There is a motor defect characterized by inability to flex the distal phalanx of the thumb and index fingers. Opponens pollicis impairment and subsequent atrophy occur.

Ulnar nerve interruption results in a sensory loss characterized by involvement of the little finger, one-half of the ring finger and the corresopnding portion of the palm and the dorsum of the hand, if the section is high enough to be above the dorsal cutaneous branch. There are marked motor phenomena in ulnar nerve involvement, with impairment of finger adduction and abduction, thumb adduction and inability to flex the proximal or distal phalanges of the ring and little fingers. An accurate diagnosis can be based upon a sensory loss in the majority of patients.

Radial Nerve. The important feature of radial nerve interruption is wrist, finger and thumb drop with little or no sensory loss. Interruption of the posterior interosseous branch in the forearm impairs only digital extension. The possibility of extensor paralysis from the section of tendons in the forearm should also be entertained.

Musculocutaneous Nerve. The diagnosis of injury to this nerve is based upon the presence of paralysis of the biceps muscle. There is loss of sensation on the anterolateral surface of the forearm (lateral antibrachial cutaneous nerve) with impaired flexion and supination of the forearm and loss of the biceps reflex.

Auxillary Nerve. A paralysis of the deltoid muscle is diagnostic of axillary nerve dysfunction. This results in weakness of abduction of the arm to the horizontal plane and a sensory defect over the deltoid muscle.

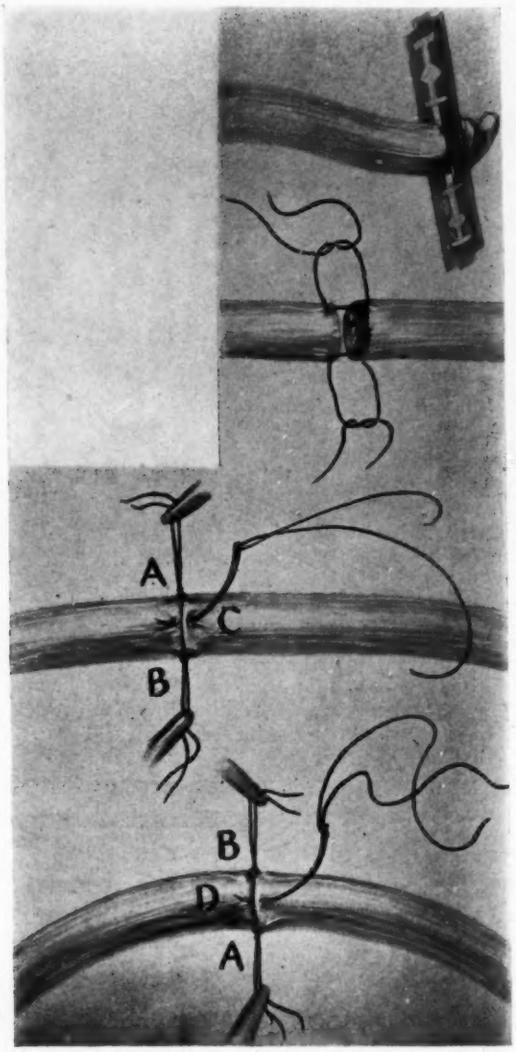

Fig. 2. The technic of nerve suture in fresh wounds. The nerve ends are débrided with a razor blade. Sutures are passed at A and B; an interrupted suture is used at C. Then the nerve is turned over and another interrupted suture is placed at D. It is important to keep the nerve ends in their anatomic position.

Brachial Plexus Involvement. A laceration of the supraclavicular region of the neck with varying degrees of paralysis of the upper limb denotes brachial plexus dysfunction. The upper plexus involvement results in a disturbance in the function of the axillary, musculocutaneous and median (partial) distribution. A lower brachial plexus involvement is manifested in median, ulnar and radial paralysis.

Multiple Nerve Involvement in the Upper Extremity. In many instances more than one nerve is involved, e.g., median and ulnar in wrist lacerations. This type of section may be complete or incomplete, giving varying patterns of sensory loss some of which are confusing.

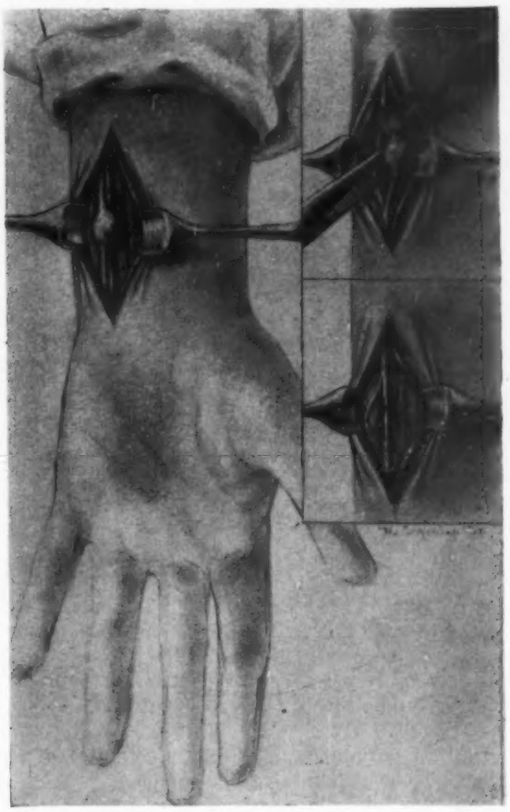

Fig. 3. Neuromatous degeneration of the ulnar nerve from partial section. The neuromatous portion is carefully dissected free from the non-neuromatous portion. The neuroma is excised and the ends of the nerve are sutured.

In the lower extremity the sciatic and its two terminal branches, the peroneal and tibial, are infrequently injured in civilian lacerations. The femoral is even less commonly involved. The leading and gross diagnostic features of interruption of these nerves may be summarized as follows: *Sciatic nerve:* Paralysis of flexion and extension of the foot and toes accompanied by a large area of anesthesia involving the foot and leg may be readily observed. The hamstring muscles may be involved in high interruption. *Tibial nerve;* There is paralysis of flexion of the foot and the toes with sensory loss over the sole of the foot. Foot inversion is also impaired. *Peroneal nerve;*

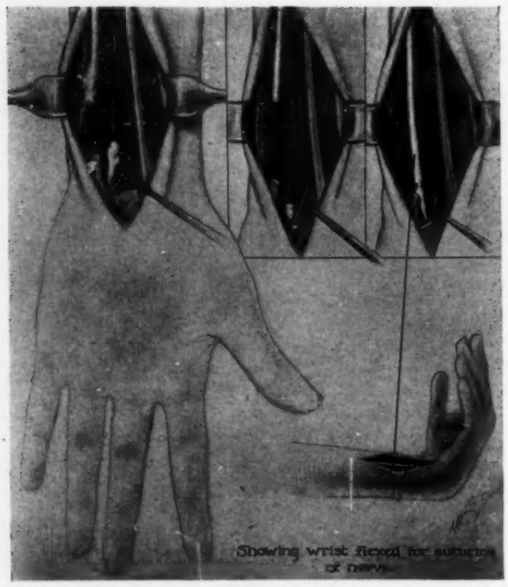

FIG. 4. Old ulnar nerve section. The neuromatous portions of the proximal and distal ends are excised with a razor blade and the nerve is sutured with interrupted silk. The wrist is flexed to obtain suture without tension.

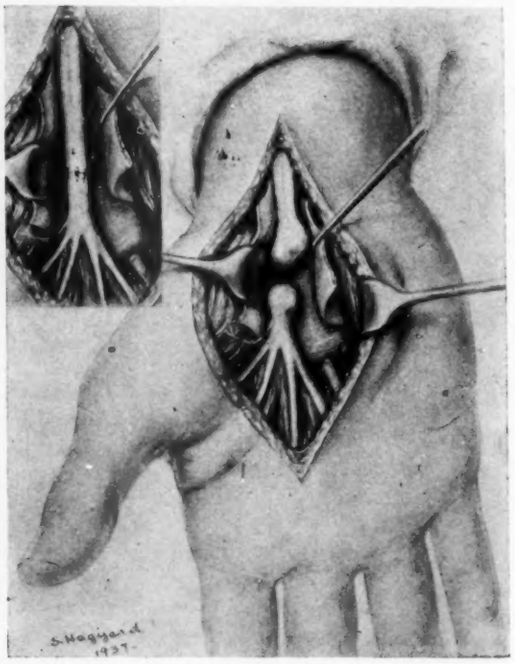

FIG. 5. "Faucet injury" of the interthenar region at the wrist-palm junction, with section of the median nerve.

A characteristic paralysis of extension and inversion of the foot and toes with sensory loss along the dorsum of the foot and the lateral aspect of the leg is present. *Femoral nerve:* There is paralysis of the quadriceps femoris with a sensory defect along the anterior and medial aspect of the thigh and leg. Extension of the leg is lost as is the patellar reflex. The thigh cannot be flexed on the abdomen.

Sacral and lumbar plexus involvement is uncommon in civilian practice. Such injury results in complete or partial paralysis in the distribution of the sciatic and the femoral nerves.

The associated occurrence of injury to tendinous and muscular structures should be considered and the extent of the non-neural involvement carefully ascertained prior to nerve exploration. A preoperative evaluation of the extent of both nerve and tendon involvement is important. The wound should never be entered before such a clinical assessment of the extent of damage has been made and recorded. Tendons, after section, may retract out of view and they may be difficult to secure unless searched for. We have seen examples of the distal ends of nerves sutured inappropriately to the proximal ends of the wrong nerves or tendons in patients with multiple nerve and tendon injuries.

OPERATIVE TREATMENT

Before the era of penicillin and sulfa therapy, the attempt was made to suture lacerated nerves before twelve hours had elapsed. In instances when suturing was not within twelve hours the wound was closed and neurorrhaphy then was accomplished six weeks after the wound had healed. The patient with a wound infection waited three months after wound healing before nerve suture was attempted. With biologic agents and chemotherapy nerves can be sutured as late as thirty-six hours after the accident. In instances where the wound had been closed the nerve repair may be done after swelling, redness and edema of the wound have subsided.

The present day plan is to suture nerves as soon as possible. Infected wounds should be permitted to heal and after healing has taken place nerve repair may be carried out in four weeks. In bullet wounds we have

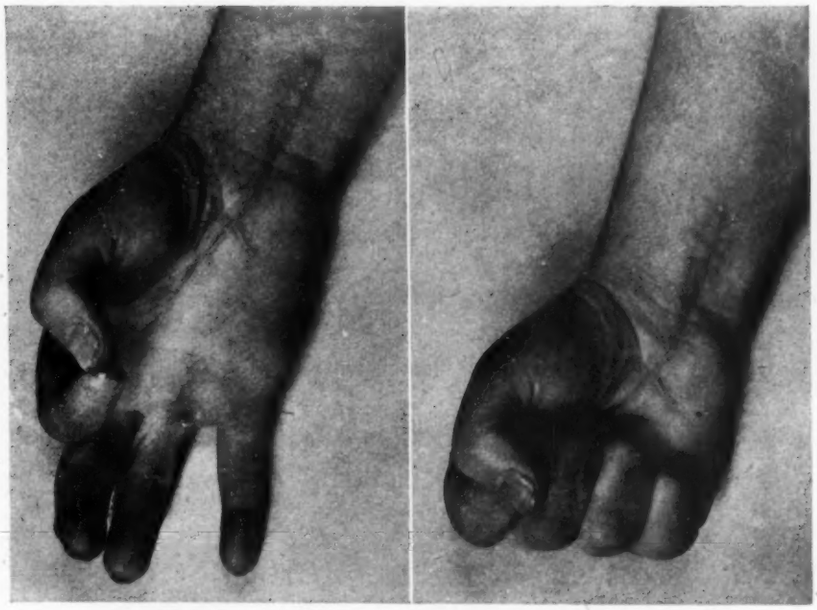

Fig. 6. Fig. 7.

Figs. 6 and 7. The same case as in Figure 5. Note the scar of the "faucet injury" at the palm-wrist junction.

learned from the experiences in World War II that it is better to wait from six to eight weeks before suturing is attempted. Whereas a few hours after injury a nerve may appear only slightly contused, six weeks afterward the true state of that nerve becomes apparent.

The operative management in primary suture consists of débridement, extension of the incision to give adequate exposure and the suture of tendinous structures as well as the sectioned nerve. If the nerve is partially sectioned, a neurolysis is performed separating the cut from the uncut portion. (Fig. 1.) The cut portion is then sutured. In complete nerve section, end-to-end suture is effected after excising the nerve ends with a razor blade. (Fig. 2.) If there is a significant gap to overcome, the nerve must be extensively dissected and freed. Transposition may be of assistance. The limb may be fixed in a desired position so as to permit end-to-end suture without tension. Three weeks are allowed for resumption to a normal position of the extremity. Nerve stretching should be avoided when possible.

In secondary suture, usually there is neuromatous degeneration at the proximal end and some bulbous enlargement of the distal end of the nerve. At times the neuromatous involvement may be due to a partial section. If so, the normal nerve bundles should be separated from the cut nerve and after excision of the neuroma the nerve ends sutured. (Fig. 3.) When the bulbous neuromas of the proximal and distal end are at a distance from each other, after excision of each neuroma, the nerve ends are sutured. (Fig. 4.) In our work we use silk No. 0000 for nerve suture as well as for the repair of sectioned tendons. During World War II the use of tantalum suture material and tantalum foil has become popular. As suture material it has been held that tantalum produces less tissue reaction than silk; it is more secure in the event of infection and it permits a visualization of suture line separation by means of roentgen studies.[4] The use of tantalum foil to surround a suture line has been employed mainly to prevent scarring in this vulnerable and strategic point. It has also been suggested that a tantalum sleeve acts to direct the peripheral growth of the interrupted axones. Certain disadvantages have been recognized as concern the use of the tantalum sleeve; it may jeopardize the

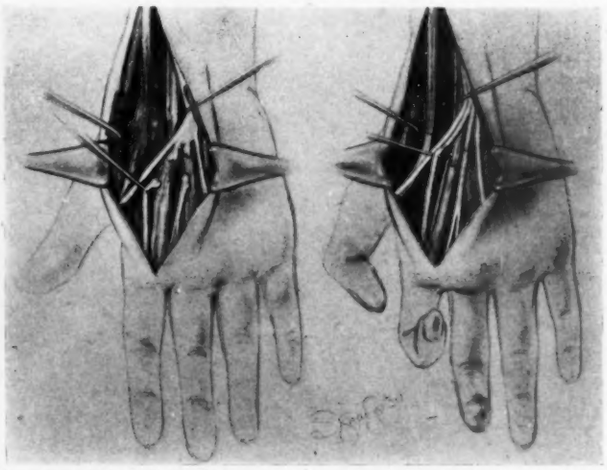

FIG. 8. "Faucet injury" of the interthenar region at the palm-wrist junction with section of median nerve branches and the flexor tendons of the thumb and index finger.

FIG. 9. FIG. 10.
FIGS. 9 and 10. The same case as in Figure 8 one year later with good return of function.

blood supply of the nerve and there may be fibrosis at the junction of the end of the sleeve and the intact nerve.[5] Therefore, the use of a tantalum nerve wrapping appears to be undesirable. There is little or no objection to the suture material.

Of particular interest are those patients having "faucet injury" wounds with laceration of the interthenar region at the palm-wrist junction. Although such wounds look benign, there may be varying degrees of involvement of major structures. In our experience complete or partial section of the median nerve, or in more distal injuries, of one or more branches has occurred. (Figs. 5, 6 and 7.) Occasionally, the flexor pollicis longus tendon and/or the flexors of the index finger were lacerated. (Figs. 8, 9 and 10.) With such extensive involvement it is apparent that early diag-

Fig. 11. Fig. 12.

Figs. 11 and 12. Tardy ulnar neuritis due to valgus deformity of right elbow. Note the atrophy of the adductor pollicis and interossei. This patient also had hypesthesia in the ulnar distribution of the hand and some flexion deformity of the little and ring fingers of the right hand.

nosis and operative repair is essential. The individual branches of the median nerve in the palm are quite large and easily sutured.

Some authors suggest the suture of digital nerves in laceration of fingers.[6] This is particularly easy in fresh wounds and should be practiced.

The prime purpose in the surgical management is the establishment of an ideal environment for regeneration. There are many known and unknown quantities which influence this process. There are some factors which the surgeon is able to control. In brief, he must provide a proximal stump which contains axones physically capable of regeneration (excision of neuromatous end) and the distal stump must be receptive to axonal growth (excision of bulbous end). The point of anastomosis requires every effort to eliminate scar provoking influences. Internal stump scarring can result in interruption of axonal growth and complete failure. External stump scarring can result in a delayed arrest of function which is equally unsatisfactory. Therefore, stump trauma and excessive manipulation should be avoided. The most reactionless type of suture material should be used. Hemorrhage should be prevented by proper stump apposition without tension. It is important to keep the nerve stumps in their anatomic position in order to match the fascicular topography. Early nerve suture is of physiologic necessity since as time proceeds there is a gradual but progressive distal segment fibrosis and atrophy. This, with the associated muscle atrophy of the part supplied and the articular fibrosis and trophic disturbances, leads to irreversible conditions preventing rehabilitation of the part.

Nerve Injury in Association with Fractures and Dislocations

Nerve injury in association with fracture and dislocation may be primary or secondary. The diagnosis of a primary nerve injury is often overlooked. The complication is discovered several weeks after removal of a cast or splint.

In our group of patients the radial nerve involvement was the most common and was associated with fractures of the humerus. The type of nerve involvement is given in Table II.

Table II

Cases of Nerve Injury in Association with Fracture and Dislocations[7]

Radial	32
Ulnar	9
Median	3
Peroneal	8
Sciatic	1
Total	53

Of particular interest are the patients with peroneal nerve involvement in adduction injuries of the knee. The likelihood of nerve laceration is great, if there is a fracture of the proximal end of the fibula. The

FIG. 13. Tardy ulnar neuritis of the right hand in a patient with no evidence of valgus deformity of the right elbow. Scarring at the epicondylar groove of an old injury caused the irritation.

skin overlying the knee may be intact. Early exploration of primary peroneal paralysis is desirable in injuries of the knee joint with fractures of the upper end of the fibula. In general, it may be stated that a nerve should be explored if there is no evidence of regeneration three to four months after the fracture of a neighboring bone. In compound fractures associated with nerve lesion, earlier repair is feasible with biologic agents and chemotherapy as adjuncts in management. In fractures of the middle third of the humerus, complicated with radial paralysis, exploration in eight to ten weeks is justifiable if there is no evidence of returning function.

In dislocations of the shoulder joint, the axillary nerve and the lower portions of the brachial plexus may be involved. There is no evidence that operative treatment of this complication is any more successful than conservative management. Fractures and dislocations about the elbow may be

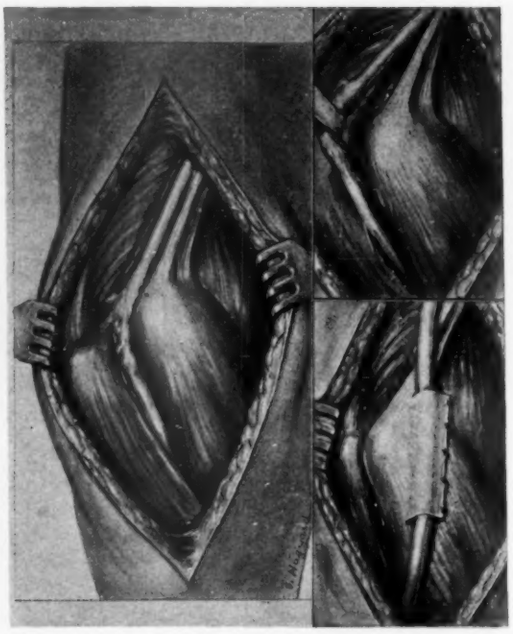

FIG. 14. Transposition of the ulnar nerve to the anterior aspect of the elbow joint in cases of tardy ulnar neuritis. Neurolysis may or may not be necessary.

associated with nerve injury and in one of our patients the median nerve was found within the elbow joint after reduction of a dislocation. It has been pointed out that acute palmar flexion of the wrist in the treatment of Colles fracture may result in median nerve involvement. It is also stated that dislocation of the carpal lunate anteriorly may produce median interruption at the wrist. In dislocation of the hip joint there is rare involvement of the sciatic nerve.

LATE OR TARDY NEURITIS (USUALLY ULNAR)

Tardy ulnar neuritis, described by Panas,[8] is commonly encountered. A few instances of late median neuritis have been described. We have seen an example of late neuritis of the sciatic nerve due to gunshot wound eleven years after injury.

Tardy neuritis of the ulnar nerve may be produced in the following two manners. First, injury in childhood to the lateral condyle with improper union results in valgus deformity of the elbow. (Figs. 11 and 12.) Several years later, increasing bony and soft tissue tension upon the ulnar

nerve results in its dysfunction with both sensory and motor phenomena. Paresthesia and atrophy are common. Second, tardy ulnar neuritis may also result from arthritic and minor injuries in the medial epicondylar neighborhood, with adhesions between the nerve and surrounding tissues resulting in chronic irritation with eventual ulnar dysfunction. (Fig. 13.) The treatment of this condition by transposing the ulnar nerve to the anterior aspect of the elbow and neurolysis when indicated is well standardized and accepted. (Fig. 14.)

REHABILITATION

Splints of affected parts are, in general, of little help in rehabilitation. The advantage of preventing overstretch of muscles is offset by the disadvantages of immobilization, resulting in inactivity of the affected muscles. The patient looks upon the splint as a form of treatment and overlooks the insidious fixation of the joints and muscle atrophy; however, patients with dropped wrist, shoulder or foot should have the parts neutralized, especially during sleep.

The plan of rehabilitation for the patient with peripheral nerve injury must begin immediately after trauma. As early as possible the patient must be instructed and repeatedly advised regarding the importance of continuous physiotherapeutic exercise of the affected part. Instead of maintaining a passive rôle, an active, interested and cooperative viewpoint must be indoctrinated in the patient.

Any surgical procedure is but a single step in the treatment. A successful result also depends on continuing exercise performed through a period of months. The patient cannot simply be told to exercise his extremity. He should be taught the gross fundamentals of the anatomy and physiology of the involved part and the rôle of occupational physiotherapy. This can best be done by a therapeutist who with adequate facilities can teach and encourage progress. The facilities are simple devices which stimulate the patient to exercise and illustrate muscle movements which he in turn can imitate. It is of importance that the patient participates in the experiences and progress of those also employing the physiotherapy and occupational facilities. He can be impressed by seeing the retarded patient who neglected his hand or he can be stimulated by the progress of the cooperative patient.

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EMERGENCY EYE CARE IN GENERAL PRACTICE*

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OCULAR injuries constitute but a very small part of the multitude of conditions those in the general practice of medicine are called upon to treat. Because of their relative infrequency, however, the physician is often at a loss as to the proper approach in their management. This feeling of hesitancy is heightened by the realization that improper care may cost the patient his eyesight. It is not always possible nor always necessary to refer these patients to those especially interested in eye care since most ocular emergencies can and should be cared for by those who first see the patient. Delay caused by sending the patient some distance to a specialist may in itself result in a poor outcome. With such a thought in mind let us review some of the more common emergency ocular conditions and make some suggestions that may help in obtaining a good result.

Probably the most common eye condition seen in general practice is the corneal foreign body. In removing the foreign substance it is necessary to have adequate anesthesia, good illumination and good magnification. Without these aids the operator is more than likely to scrape off a large area of corneal epithelium and thus add to the severity of the patient's injury. Adequate anesthesia is best obtained by drugs such as ½ per cent pontocaine which does not soften the corneal epithelium and thus promote epithelial stripping such as is obtained with cocaine. A Beebe binocular loupe and small pencil flashlight together with an assortment of sterile foreign body spuds complete the equipment. If foreign body spuds are not at hand a small sterile hypodermic needle on a small Luer syringe will suffice. Many foreign bodies can be removed by simply brushing them off the cornea with a wet cotton applicator. It is necessary to remember that the charred tissue about the actual foreign body must be completely removed if the lesion is to heal. It is my practice to instill butyn-metaphen ointment and pad these eyes for a few hours following foreign body removal. If there is ciliary injection and the area of trauma in the cornea is hazy, uveitis and ulceration are probably present and the patient might better be turned over to your ophthalmologist. Foreign bodies imbedded in an area 6 mm. in diameter in the center of the cornea must be handled with great respect since this area is the optical zone of the cornea. Even faint scars of this zone will result in considerable permanent visual loss.

Corneal abrasions undoubtedly are next in order of frequency. These are often missed by the examiner if the abrasion is not stained with 2 per cent aqueous fluorescine. Abrasions usually heal readily in a day or two by instilling some combination ointment such as butyn-metaphen or metacaine-merthiolate and tightly padding the eye.

Blunt, non-perforating, contusive injuries to the eyeball are rather frequent among children. Fortunately the protection afforded by the bony orbital rim prevents most of these injuries from doing serious harm. The plebian black eye is best treated, if seen immediately, by applying continuous ice compresses. This will largely control the edema. Hot wet compresses may be preferred if the process is seen later when edema is present. The heat will merely hasten the absorption of blood. If it is necessary for the injured individual to make a public appearance, the dis-

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coloration of the lids may be masked by the use of the cosmetic labeled "Cover Mark" which may be secured from any beauty parlor.

Contusive injuries to and about the eye should not be passed over lightly, however, until the orbital rim and interior of the eye have been thoroughly searched for more serious damage. Fractures of the orbital rim showing considerable depression may result in displacement of the eyeball and disturbances in its motility. Such displaced fractures should be replaced at once or as soon as the edema has subsided.

A subluxated lens, resulting from contusion, will not respond to treatment but by discovering its presence, embarrassment to the examiner may later be avoided. The same is true as regards vitreous hemorrhage or ruptures of the choroid. When the latter conditions are found the eye should be watched for development of retinal detachment. Should detachment of the retina occur, immediate ophthalmological care is imperative.

Blunt injuries to the globe not infrequently are followed immediately or later by massive anterior chamber hemorrhage. This complication is one which requires careful observation and unless you are sure of your grounds you might better shift the responsibility to an ophthalmologist. Most anterior chamber hemorrhages will absorb fairly readily with the use of 1 per cent eserine or 2 per cent pilocarpine, four times a day, together with hot compresses. Others may persist or result in a secondary rise in intra-ocular pressure. Since this pressure, in the presence of anterior chamber hemorrhage, leads to the development of blood staining of the cornea, the increased pressure must be relieved immediately by corneal paracentesis. The use of eserine or pilocarpine will have no influence on the pressure and valuable time should not be lost in trial. I have yet to see an eye showing blood staining of the cornea which eventually obtained useful vision. I have not seen blood staining of the cornea result from anterior chamber hemorrhage when there was no increased ocular pressure. These two observations emphasize the necessity for early recognition and correction of the glaucoma in this type of ocular trauma.

The anterior chamber hemorrhage from blunt non-perforating contusion to the eyeball often results from lacerations of the iris. The weakest part of the iris is its attachment to the ciliary body. Laceration of the iris at this point results in a pulling away of the iris at its base. If this is severe, the pupil is usually strongly displaced towards the opposite side. Slight to moderate displacement of the pupil gives no visual impairment, but marked pupillary displacement gives marked loss of vision. These latter cases indicate the need of surgical correction.

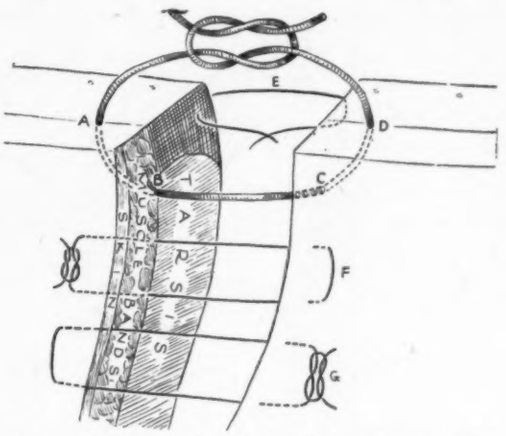

Fig. 1. Transmarginal laceration of lower eyelid. A, B, C and D, points of entrance and exit of suture uniting intermarginal groove; E, deep buried gut sutures uniting tarsal plate; F, sutures uniting obicularis muscle bundles, either buried or not; G, cuticular sutures.

Perforating injuries to the eyeball by flying particles point to the desirability of *x*-ray of the globe. *X*-ray of the eye should be done in all instances in which the history suggests the possibility of intraocular foreign body. Many of these eyes have an obvious perforation of the globe, but in others careful search reveals no point of entrance. An undiscovered intra-ocular metalic foreign body may give no symptoms for years. More commonly they result in recurrent iridocyclitis, endophthalmitis,

cataract or siderosis bulbi. Once the retained foreign body has rusted away and the rust disseminated through the eyeball, the globe becomes phthisical. Those physicians connected with industrial first aid stations or those not especially interested in eye care should not burden themselves with the responsibility of caring for these patients. A fairly high percentage of enucleations eventually follow perforating ocular injuries.

With the advent of relatively inexpensive ultraviolet lamps, their use in the home is becoming more common. The users of these lamps sooner or later become careless and do not adequately protect the eyes while taking a sun bath. Since the eyes are sensitive to infra-red and ultra-violet rays nearest to the visible spectrum we occasionally see these people with violent edema, photophobia and pain. No permanent damage is produced by this severe reaction but adequate care is needed to give comfort. Ice compresses, dark room and the instillation of phenocaine-epinephrine ointment will give almost complete relief. Arc welders and electricians receive similar types of electric ophthalmia.

There are many types of chemical burns involving the eyes and in general they are to be considered as serious. The alkalies are usually more damaging than the acids in that they have a tendency to keep on working deeper and deeper into the tissues while the acids coagulate the proteins of the surface cells and thus produce a more superficial lesion. Ciccatricial contraction of the conjunctiva result in symblepheron of varying degrees.

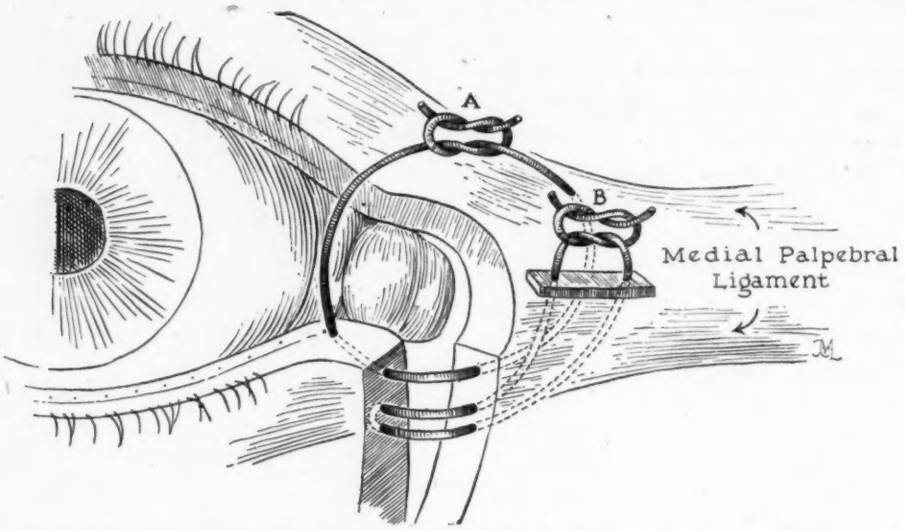

FIG. 2. Laceration of eyelid at inner canthus severing lower lacrimal canaliculus. A, heavy chromic gut suture threaded through the canaliculus and into the lacrimal sac, coming out through the skin at the upper pole of the sac; B, traction suture anchoring severed lid to the internal palpebral ligament. Deep conjunctival gut sutures, orbicularis muscle sutures and skin sutures inserted in layers to close remainder of lid defect.

The first treatment is the most important. Speed and thoroughness are the main requisites for a satisfactory end result. Chemical burns should be treated immediately by copious washing with tap water. The more water used the better. Care must be used to evert the eyelids no matter how serious the blepharospasm. Only too frequently the plaster, lime or other chemical is left in the retrotarsal folds to act over a long period of time. No attempt should be made to neutralize an acid with an alkali, etc. Adhesions should not be allowed to form between bulbar and palpebral conjunctiva. By passing a small, smooth, glass rod covered with vaseline between the lids and globe once

or twice daily symblepharon may be prevented.

Lacerations involving the margin of the eyelid require immediate and accurate repair if cosmetic defects and functional disturbances are to be avoided. Most of the textbooks on ophthalmic and plastic surgery deal with methods of correcting the late deformities which result from lacerations of the eyelids. More emphasis should be placed on methods of preventing deformities resulting from recent lid trauma. The physician who first cares for these patients has the best opportunity of giving a good cosmetic and functional lid. Lack of an appreciation of this fact often results in hasty and bungled repairs which later have to be reoperated with less chance of a satisfactory result.

Lacerations of the eyelids may be of relatively minor importance compared with the shock and other more serious trauma which the patient may have coincidently. Rather than make hasty and inadequate repairs under these circumstances, the eyeball should be covered, if exposed, and the repair of the lid lacerations left until a time when more meticulous care can be expended on their suturing. The longer the interval between injury and repair, the more edema is present. This edema distorts the tissues of the lids and to some extent complicates the surgery. If ice compresses are kept on the lids until the surgery can be started, much of the edema can be prevented.

Extramarginal lacerations require more care than do lacerations elsewhere on the body surface. It is necessary to recall that there is very little tension on the tissues of the lids and therefore much finer sutures and needles should be used to give the least possible scar. Use No. oooooo black silk with atraumatic needles for all skin and conjunctival repairs of this type. No silk, gut sutures or knots should ever be allowed to come into contact with the cornea from the inner surface of the lid. For proper lid action it is imperative that extramarginal lacerations severing orbicularis muscle bundles be reunited as a layer. This is best done with No. ooooo mild gut sutures on atraumatic needles. When the levator tendon is severed, it should be isolated and sutured with No. ooooo medium gut to prevent ptosis. It is far more difficult to make this correction in a healed deformity. If meticulous cleansing of the wound is carried out, no drainage tubes need be inserted. Only crushed tissues are excised.

Transmarginal lid lacerations, on the other hand, require even more meticulous repair if the results are to be both cosmetic and functional. Here again we must stress the need for using fine sutures and atraumatic needles and the least débridement possible. No. oooooo silk is used on the skin surface and No. ooooo or No. oooooo gut is used for the buried sutures.

The most important suture to be placed is that uniting the intermarginal groove. This is the grey line situated between the openings of the Meibomian glands and the eyelashes. If the first suture placed passes through this line down into the substance of the tarsus and then across the line of laceration to enter the tarsus at the same distance from the lid border and comes out in the intermarginal line on the other side of the laceration (Fig. 1), the lid border will be in perfect alignment. This enables us accurately to insert the deep buried gut sutures closing the tarsoconjunctival surface and the superficial silk sutures closing the orbicularis muscle and skin. Silk, gut sutures or knots should never be left in contact with the corneal surface since the movement of the globe will cause abrasion and scarring.

Minsky[1] has made helpful suggestions which aid in obtaining smooth union of the lacerated lid border. He splints the two lid borders together by passing the sutures uniting the lacerated lid margin through the opposite contacting lid border and then brings the sutures out through the skin above the lashes, tying them over a rubber plate. Where more than one laceration of the lid border is present, this splinting suture method of Minsky may be

utilized with advantage. Should the transmarginal lid laceration involve both lids at the same point, Minsky's figure-of-eight suture may be used. This gives perfect alignment and splinting of both lid borders. The deep buried conjunctivotarsal gut sutures and the superficial musculocutaneous silk sutures are inserted as previously mentioned.

Special precautions are necessary when lid lacerations involve the external or internal canthus. Should the external canthal ligament be severed or evulsed, the lids are not held tightly against the globe and epiphora and ectropion will result. It is therefore necessary to see that strong No. oooo gut sutures unite the severed ends of the ligament. Should there be tissue loss and the ligament not identified, the outer ends of the tarsal plates should be united by sutures with the periosteum behind the lateral orbital rim at the point conforming to the outer canthus. The orbicularis muscle fibers near the lid border should be included in the cutaneous sutures since these muscle fibers play an important rôle in keeping the lid border from turning out in ectropion. The intermarginal sulcus is again utilized in lacerations at the outer canthus since a suture passed through this line below the canthal laceration and then across the laceration to come out in the intermarginal sulcus of the other lid will perfectly reform the canthal angle.

Lacerations and evulsions of the inner canthus involve even more important anatomical structures since only too commonly the lacrimal passages are severed. Unless the inner canthus is properly restored and the lacrimal passages remain patent, troublesome epiphora results.

When the laceration goes across the lower canaliculus, a heavy chromic catgut suture is threaded through the punctum and canaliculus and through the medial cut end of the canaliculus and into the lacrimal sac. (Fig. 2.) The needle is brought out through the upper pole of the lacrimal sac and through the skin above the internal palpebral ligament and tied.

It is necessary to anchor the inner end of the severed lid to the internal palpebral ligament or periosteum. This is best done by passing a double armed No. 2 braided silk suture through the conjunctival surface of the torn lid to come out below the severed canaliculus. These sutures are then passed through the torn mesial lid tissues below the canaliculus and directed upward to engage the canthal ligament in an attempt to anchor the lid at this point. These sutures are brought out through the skin and tied over a rubber plate. (Fig. 2.) The skin and orbicularis muscle are united in layers after the depth of the wound is closed with buried gut as in the transmarginal lacerations.

SUMMARY

Ocular injuries should receive immediate meticulous care. The majority of such injuries can and should be the responsibility of the physician first seeing the patient. The simplest of ocular trauma may result in loss of eyesight but this can usually be prevented by following a few simple rules of ocular care. Lacerations of the lids cannot be sutured in the same manner as simple lacerations elsewhere on the body surface. The peculiar and complex anatomy of the eyelids must be maintained if function is not to be disturbed.

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CHEMICAL BURNS OF THE HUMAN CORNEA

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WITH the advent of the present chemical age it behooves not only the ophthalmologist but all doctors to have a working knowledge of how a chemical burn of the human cornea should be handled. Following the publication of the author's original paper in The American Journal of Ophthalmology (November, 1946), on this subject he has been more than amazed at the response he has had, not only from the industrial group but also from the general practitioners. It is his definite knowledge now that many of these burns are never seen by the ophthalmologist for various and sundry reasons. Let us appeal to each and every doctor to learn this treatment in detail and follow as closely as possible the routine, in case of these most dangerous of burns. The author does not present this as the ultimate in treatment but for the present it is an effective method in a vast majority of patients. Much work is being done at the present time and there is no doubt that this more or less generalized treatment will be detailed to certain definite treatments for the various chemicals.

A chemical burn of the cornea is defined as an injury which results from local contact with a chemical (solid, liquid or vapor) to such a degree that there is alteration in the structure of the cornea and conjunctiva. This alteration in structure is demonstrated by a positive stain when a 2 per cent buffered solution of fluorescein is applied. With that definition in mind let us consider the method of treatment. The author believes that it can be divided into three sections: (1) Immediate first aid, (2) secondary first aid and (3) specialized or medical treatment. The same steps apply regardless of whether the chemical is solid, liquid or vapor.

IMMEDIATE FIRST AID

The immediate treatment of an eye burn is at the site of the accident. Specially built foot-operated eyewashing fountains are provided close at hand in every working area. (Fig. 1.) The injured eye is washed thoroughly and at once with tap water, holding the lids open with the hands. No neutralizing substances are used since study of this practice reveals that not only do they do no good but that actually some are injurious in themselves. After the preliminary washing the victim is at once transported to the medical dispensary where equipment for first aid is held ready at all times.

SECONDARY FIRST AID

When a patient with a chemical eye burn is brought into the dispensary he is placed in a reclining chair (Beck) and tilted back over a catch basin. The eye is inspected and then anesthetized with 0.5 per cent pontocaine solution. Gross particles are removed with a moist cotton applicator. The eye is then irrigated with a continuous flow of normal saline, no pressure being exerted on the eye. Special equipment (Figs. 2 and 3) consists of a 5 gallon bottle mounted on a movable stand and equipped with a siphon (3 foot head). Irrigation is continued for fifteen minutes, after which time the eye is re-examined for gross particles and then stained with fluorescein. If the eye is damaged the injured cells will assume a typical fluorescent yellow-green stain. If a stain is observed, further anesthesia is produced with pontocaine and washing proceeds for another fifteen minutes. The stain is applied a second time and if found positive the patient is considered to have an unequivocal chemical burn and

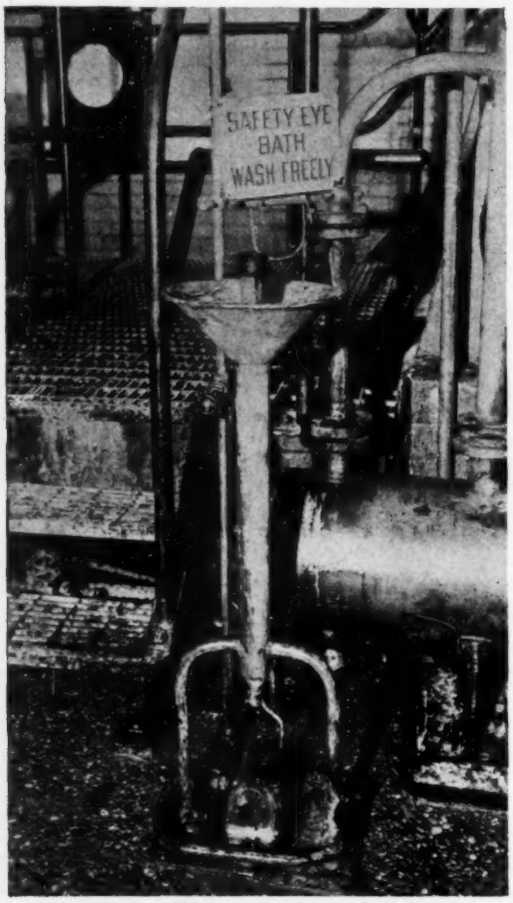

FIG. 1. The eye bath on the job.

is referred to the ophthalmologist. Time here is of importance, and it has been the writer's experience that no more than two hours should elapse between the moment of the burn and the time when special treatment is rendered. Certainly, the prognosis grows worse as time passes and a delay of six hours almost always results in some loss of vision.

SPECIALIZED OR MEDICAL TREATMENT

We term this technic as denuding. When the author began the study of chemical burns of the eye seven years ago, it was a debatable question whether or not some chemicals had a "delayed action." Such compounds frequently caused a loss of vision due to opacification of the cornea and adhesions of the conjunctiva following a symptom-free period of several hours after accidental contact. In searching for a scientific basis for this behavior the most notable finding was the change in corneal structure produced by all alkaline and a few neutral organic compounds but not by acidic compounds nor those neutral chemicals which experience shows to be relatively harmless.

The corneal structure is best observed with the high power of the biomicroscope under retro-illumination, with occasional resort to direct illumination. The change consists in the presence of areas of opacity in the superficial layers of the corneal epithelium. They vary in size, possess a grayish tint and have well defined margins. They suggest keratitic deposits but direct illumination reveals that they lie immediately posterior to the precorneal film in the most superficial epithelial layers anterior to Bowman's membrane. The opaque areas are seen to be stained a faint green by fluorescein when observed by direct illumination.

We thought at first that the offending chemical had penetrated into the epithelial cells, there reacting with the cytoplasmic protein. However, this would bind the chemical in place and probably neutralize its ability to injure other cells. Studies reported by Carpenter and Smyth make it appear more probable that the foreign compound initially is physically adsorbed upon protein structures of the corneal epithelium. Following this, a portion of the adsorbed chemical denatures cellular protein which results in necrosis. The remainder is liberated slowly with its chemical nature unchanged, to diffuse from the original site of adsorption into previously unaffected tissue. Therefore, instead of a delayed effect there is a progressive action which may spread to involve the entire depth of the epithelium and eventually Bowman's membrane, at which point irreparable damage to the tissue results.

The greater number of chemicals behaving in this way are alkaline, and at first it appeared that neutralization of the compound bound to corneal epithelium would halt the progressive action. However, animal experiment demonstrated no

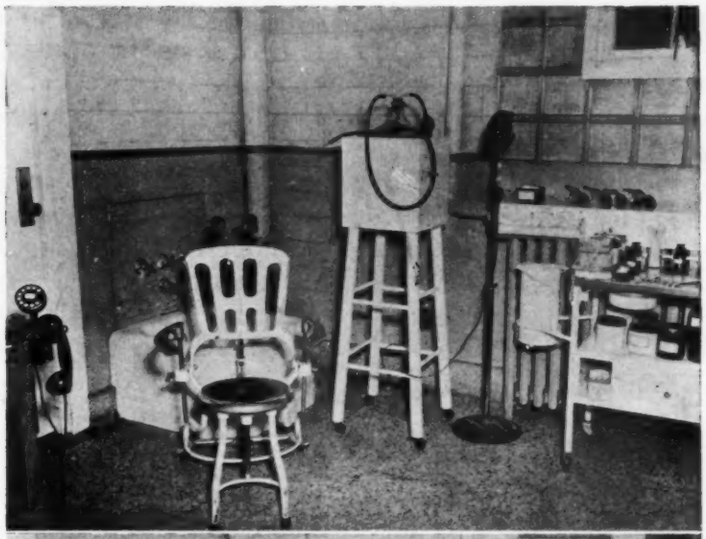

Fig. 2.

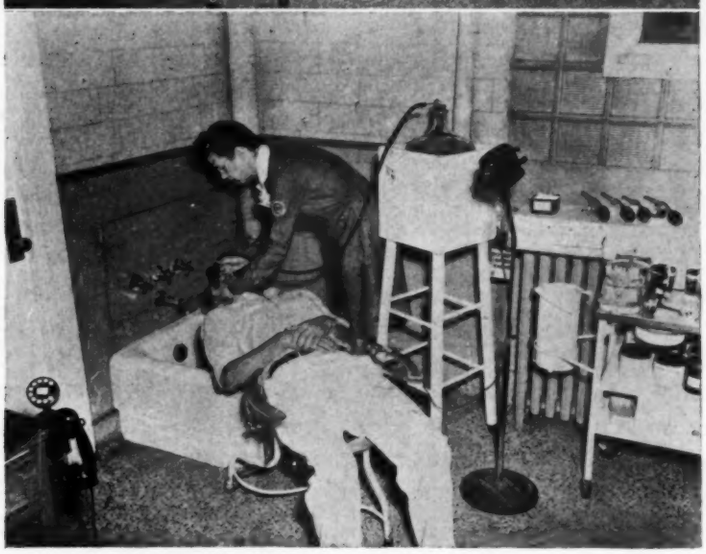

Fig. 3.

Figs. 2 and 3. Dispensary equipment.

amelioration of injury from attempted neutralization. It was then apparent that only one form of treatment was possible, that of mechanical removal of the involved cells before a progressive action could be initiated. This operation is named "denuding." As carried out by the author the manipulation differs in purpose and thoroughness of control from débridement.

No evidence for a progressive action of acids has been observed. They apparently react rapidly with cell proteins, coagulating them and themselves being neutralized in the process. The extent of an acid burn of the cornea is, of course, determined by the amount and concentration of acid in the eye and the length of time that elapses before it is washed out. The method generally used in treatment of an acid burn is to débride the dead tissue and treat the eye symptomatically. Following the appearance of the communication by Mann on corneal healing, the author clinically employed the methods described and concluded, in conflict with her findings, that the course of healing is not prolonged by removing destroyed tissue. Furthermore, its removal reduces secondary infection by eliminating the substrate for bacterial growth. Consequently, the author still considers débridement essential following corneal burns caused by acids.

The denuding technic in its early application consisted of complete removal of the epithelium down to Bowman's membrane. The biomicroscopic picture of the completely denuded Bowman's membrane is that of a smooth surface without evident cellular structure having regularly placed, minute dimples which are the rami perforantes of the corneal nerves. Although we have later shown that such radical removal of tissue is unnecessary, we do know that the epithelium is rapidly replaced and we have seen indications that the two methods of regeneration described by Mann are correct.

Denuding as used today removes only such tissue as is involved and the manipulation is controlled by repeated examination with the biomicroscope. The instrument of choice is a round toothpick swab. The epithelium is softened with a 4 per cent cocaine hydrochloride solution which also acts as a local anesthetic. The applicator is started in the center of the involved area with just enough pressure to distort the corneal surface slightly. With a circular motion the applicator is carried progressively from the center to the outside of the area where it is lifted. This action is repeated over the entire affected area until the biomicroscope reveals no more of the clouded cells but only a rough surface indicative of ruptured cell bodies and fragments of cells. After the corneal denuding is completed, a careful denuding of the conjunctiva is performed. Here the applicator is passed from the limbus to the cul-de-sacs, each lid swept from side to side and the cul-de-sacs finally swept. The eye is then flushed with a stainless solution of merthiolate which acts not only to remove the denuding refuse but also as an antiseptic.

Study of the eye during the denuding process may be confusing, for the precorneal film has been removed and allowance must be made for its absence. In the final check on the biomicroscope the meniscus of the lacrimal fluid where it meets the lower lid should be observed carefully and no cellular débris should be left. Each eye is routinely closed with 5 per cent sulfathiazole ointment (sulfadiazene is equally efficacious) and a lid immobilizing patch is applied.

During the first consultation special attention should be given to all possible foci of infection, especially the teeth. While treatment of the foci need not be started at this time it is important that they be noted on the record. Treatment is started if the eye does not heal by first intention. It has been the author's observation that more vision has been lost in chemical burns due to focal infection than by the actual effect of the offending agent.

The after-care of the chemical burn is of great importance and the author has found that the following attention to detail will be well rewarded with satisfactory results. Warning is given the patient at the first consultation that considerable pain is to be expected due to the denuding, and each patient is provided with 0.5 per cent ophthalmic pontocaine ointment with instructions to apply it aseptically to the eye as frequently as is needed in order to control pain. Some persons, due to a difference in pain threshold, will require barbiturates and a few may need morphine. The immobilizing patch is to be worn at all times except during actual treatment.

The eyes are inspected under fluorescein stain upon the day following denudation and if found to be healing by first intention no change is made in therapy. If, however, undue reaction is found, the eye is placed at temporary rest by the instillation of a few drops of 5 per cent homatropin solution and 5 per cent sulfathiazole ointment is added at four-hour intervals. The choice of homatropin is made so that loss of time, an important factor in industrial practice, will be minimized if the eye heals promptly.

On the third day inspection is again made and if healing is not complete, there is presumptive evidence that the burn has converted to an infected ulcer and active combative treatment is instituted. The eye

itself is sprinkled with methylene blue powder and the excess flushed away. Pontocaine, sulfathiazole and the immobilizing patch are continued. An intramuscular injection of 4 cc. of proteolac* is given and administration of maximum doses of sodium salicylate is started. Dental *x*-ray or medical examination of other foci is made and such areas, if amenable to treatment, are removed at the earliest possible moment, regardless of the condition of the eye. In the event that surgical treatment of foci is to be undertaken the patient is hospitalized and intravenous typhoid vaccine fever therapy is begun. The surgical procedures are so arranged that they fall on the rest day in the typhoid series. At this point the eye is atropinized, since prevention of time loss is no longer a factor to be considered and the whole attention must be turned toward the healing of the eye.

After healing has taken place and the cornea has been free from fluorescein staining areas for forty-eight hours, any residual opacity is treated with increasing percentages of dionin or with choline chloride.

* G. D. Searle & Company.

Case reports have been recorded elsewhere and will not be repeated here. The author's series now totals nearly 800 patients and he believes that he can fairly state that all losses of vision from chemical burns can be explained on the basis of failure of this reported technic in one or more of its details.

CONCLUSIONS

1. Immediate first aid followed by long flushing with water is of the utmost importance. No attempt at neutralization is recommended.
2. Specialized treatment by an ophthalmologist should be given within two hours after the injury. Further delay threatens recovery of full vision.
3. Denudation is the treatment of choice.
4. There is no mention made of conjunctival adhesions in this article and it is notable that with the technic described the author had no such complication in any of these nearly 800 consecutive patients.

FRACTURES OF THE OS CALCIS

PRELIMINARY REPORT

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THE os calcis is fractured more frequently than any other tarsal bone and in various series represents 1 to 2 per cent of all fractures. Willis C. Campbell once said that mal-union in fractures of the os calcis is so common as to be almost the usual result. In recent studies it has been determined by the use of high speed photography that the fracture is produced by the foot striking the ground in a pronated position with the tuberosity of the os calcis outward, backward and downward. The tuberosity tends to be carried upward, outward and forward, resulting in the sustentaculum being displaced downward and the long arch of the foot being flattened.

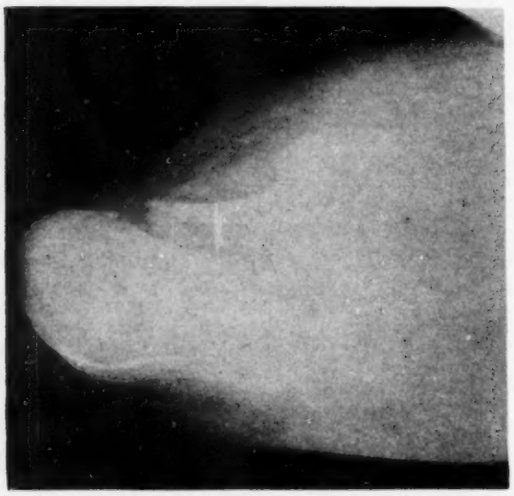

FIG. 1. *X*-ray of the os calcis at the time of the fracture revealing a typical lateral displacement of the tuberosity and interposition of the corticle fragment.

The anterior spicule of the lateral fragment produces a prominence beneath the external malleolus and this tends to persist, even after the strongest traction by pins through the os calcis and the tibia. However, the greatest deformity has been found both by *x*-ray studies and by exposure of the fracture at operation to be on the medial aspect and it is here that displacement of the fragments and interposition of a brittle fragment of the cortical bone blocks anatomical reposition.

FIG. 2. Anatomic end result obtained by open reduction.

This interposition of the fragments results from the cortex being brittle and thin, the remainder of the bone being cancellous and the explosive force of the fracture results in fragmentation of the cortex, the fragments being rotated and being driven into the cancellous portion. The posterior process is forced laterally and forward to produce a widening of the bone and foreshortening.

All of the methods which have been suggested since the time of Dr. Frederick

Cotton have failed to produce a good anatomical reposition, and feeling that an arthrodesis of the subastragaloid joint is too disabling in the case of a man who has to perform heavy labor and also feeling that the more radical procedure of excision of the bone also results in too great a disability, during the past year open reduction has been performed upon the os calcis.

At operation the mechanical blocking due to interposition of the cortical fragments has been found and with the removal of these fragments good anatomical position has been obtained. This also results in a smooth, articular surface in the subastragaloid joint.

This type of treatment has resulted in disability of four months in the severely comminuted and displaced fractures, in contrast to the two years previously estimated as the immediate disability and although a mild arthritis may develop after the years go by, in these patients the function which has resulted during a year of observation would indicate that a high percentage of partial permanent disability can be greatly lessened.

CONCLUSIONS

1. The difficulty of obtaining a good functional result in fractures of the os calcis is noted.
2. The mechanism of the fracture and the displacement is outlined.
3. The anatomical position obtained is shown by *x*-ray studies.
4. The possibility of obtaining a good functional result by open reduction is presented.

New Instruments

FINDER AND SCREW DRIVER USED IN DRIVING SCREWS WITH A DRILL

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IT has been the experience of the author and undoubtedly that of many orthopedic surgeons, that the usual method of inserting screws into plates or into grafted bone, is quite a tedious chore. In addition to the length of time required to place a number of screws into bone, there is often a considerable amount of irritation to the palm of the hand when considerable pressure is made against the screws, even though we know a correctly handled screw driver is gripped on its side, not over the back.

Not alone therefore because of the work required, nor because of the discomfort even to twisting and avulsing palmar skin that becomes caught in the glove, but also because a rapid mechanical method would also appreciably shorten the operative time and materially lessen the shock to the patient, it was felt that emphasis upon a mechanical means to drive screws should be made.

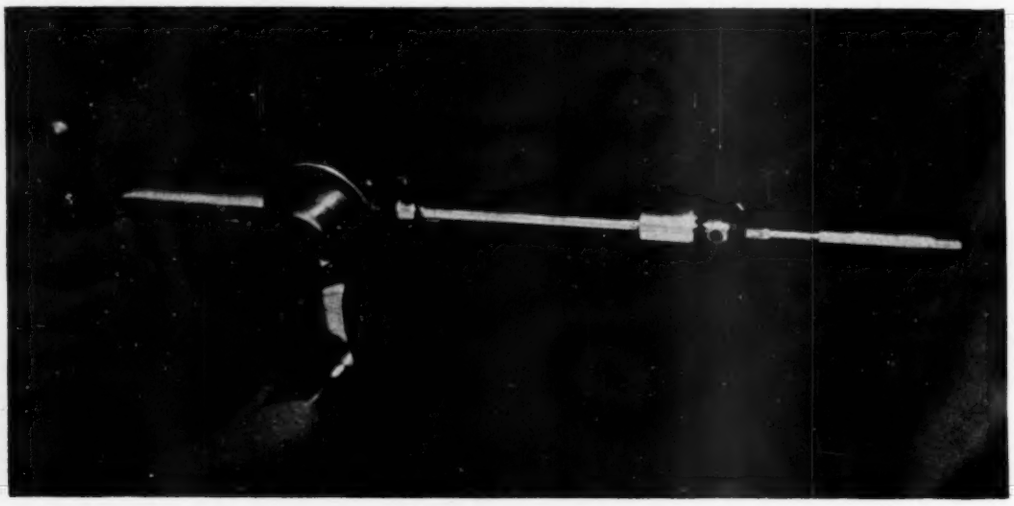

FIG. 1. Screw driver and finder.

With this in mind, we first used the end of a screw driver and placed this in the Jacob's chuck of a hand drill. We found that we could quite easily drive screws in, but occasionally the screw driver would slide out of the slot, also the apparatus made a rather cumbersome thing to first engage the slot of the screw. This was simplified by using a Phillips head screw, but still the need of a combination finder and screw driver became apparent.

Under the assumption that in modern manufacturing methods, there must be some way whereby the slots of screws are found and the screws automatically

screwed in by power tools, we assumed an apparatus containing a sleeve around a screw driver, the sleeve upon a spring, the screw driver to rotate within the sleeve. We looked around and found precisely this. The hexagonal base of this screw driver* allows it to engage in the chuck of the drill with ease and without requiring strong tightening of the chuck and there would be no slipping of the screw driver. The spring connecting the screw driver and the finder is just tense enough so that when the screws are merely placed in previously drilled holes in the bone, adequate pressure can be made to keep the screws in line. As the drill is spun the screw driver inside of the conical finder turns into the slot of the screw and then with no difficulty the screws can be driven in until they are fully tightened. As a matter of fact they can be tightened with a good drill to a point even beyond that possible by hand, for the drill gives a mechanical advantage.

The author dismantles these stock screw drivers and finders and has all parts chromium plated in order to better preserve the material.

*The "Screw Driver and a Finder" No. 17690, is made by Black and Decker.

SELF-RETAINING SKIN HOOKS*

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TO a large proportion of patients the scar resulting from an operative procedure is of major importance, especially if it is on an exposed part of the anatomy. Erroneously or not, they often judge the entire surgical procedure by the appearance of the skin incision. Because of the importance of the skin closure an aid for easier and more accurate skin closures was devised. It is a common practice for the busy surgeon to leave the closure of the operative wound to his assistants, thus leaving to two people a task which often requires three. In many individuals, especially the obese, there is often distortion and gaping of the wound even after the approximation of the subcutaneous fascia and tissues. The usual skin hooks are manually held, applying tension to each end of the wound, thus causing the two edges of the wound to come together. Since they are held by an assistant, he is lost as an aid to the actual closure of the wound and is often a hindrance because one of his arms is in front of the surgeon. This loss often becomes evident in the result and in the amount of time required to complete the closure. Our skin hooks are designed to liberate the assistant so that he may participate more actively in the closure.

FIG. 1. Illustration of self-retaining skin hooks.

The self-retaining skin hooks illustrated (Fig. 1) employ the tension-lock principle common to many other instruments, among them the Frazier laminectomy retractor and a self-retaining retractor recently designed by ourselves.[1] In addition, however, locking thumb screws have been applied to the two freely movable arms so that marked tension is not necessary to maintain the instrument in the position desired. The skin hooks are applied to each end of the wound and are then separated with adequate tension so as to approximate the two edges of the wound. If the wound is long, curved or sharply angulated, the instrument can be applied to one segment of the wound at a time. The bar is 12 inches in length, making the instrument adequate for most incisions commonly employed. The bar is also conveniently removed to one side facilitating the placement of the sutures.

The self-retaining skin hooks here described are designed for the accomplishment of more cosmetic skin closures with greater facility. This aim has been realized by us in the closure of devious types of skin incisions on a busy surgical service.

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* From the Second Surgical Division (Cornell), Bellevue Hospital, New York, N.Y.

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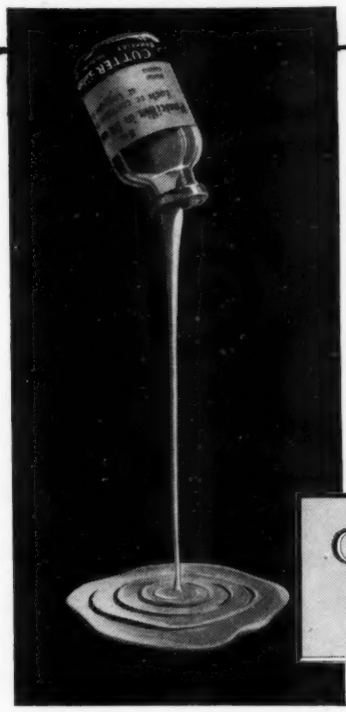

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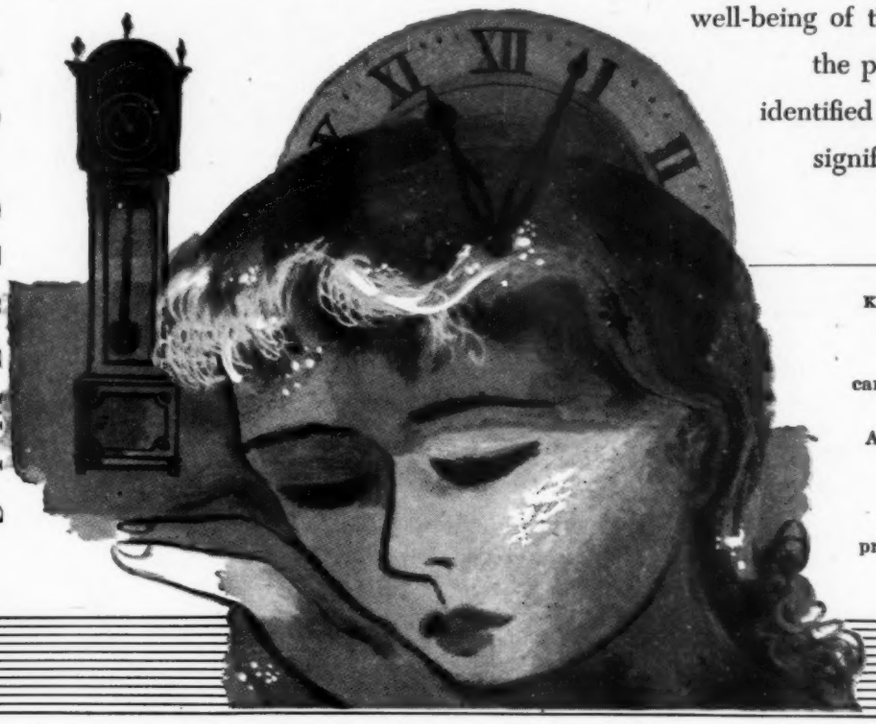

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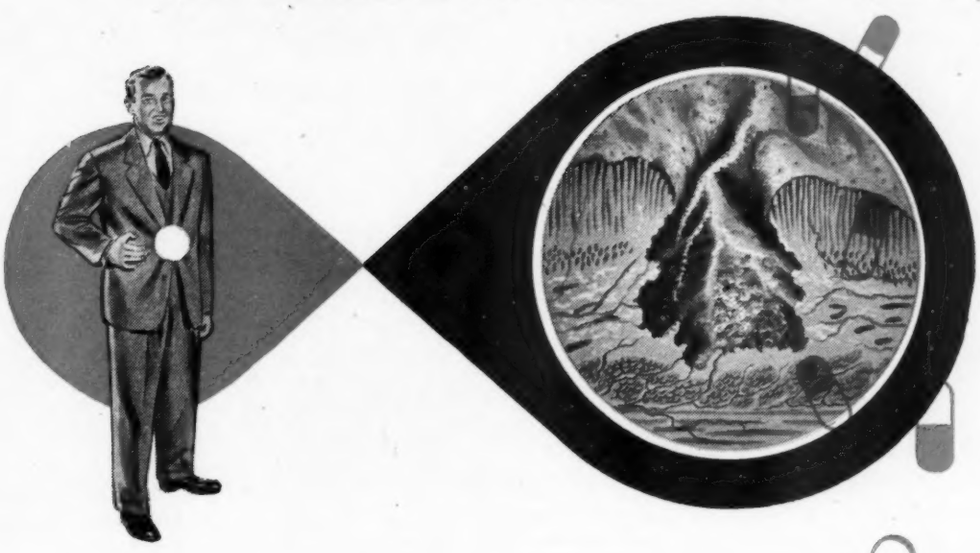

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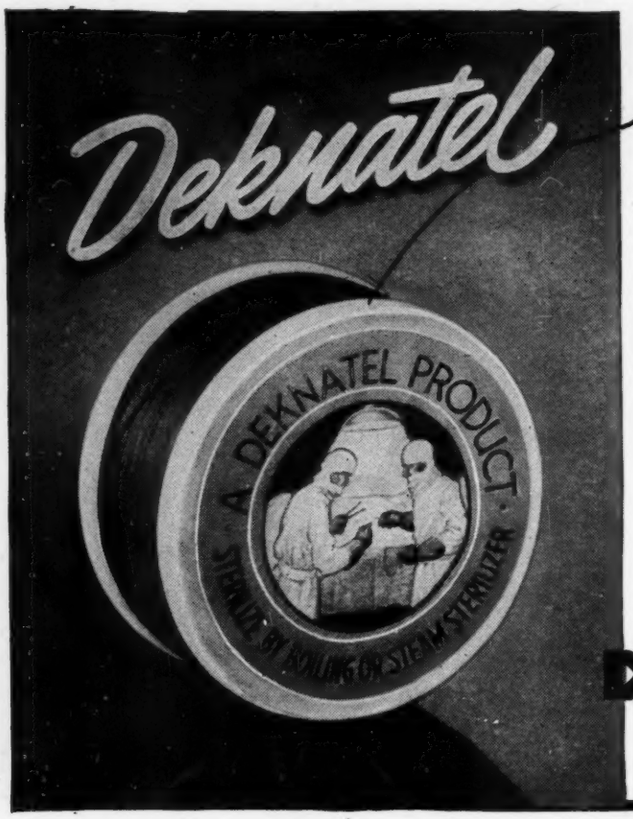

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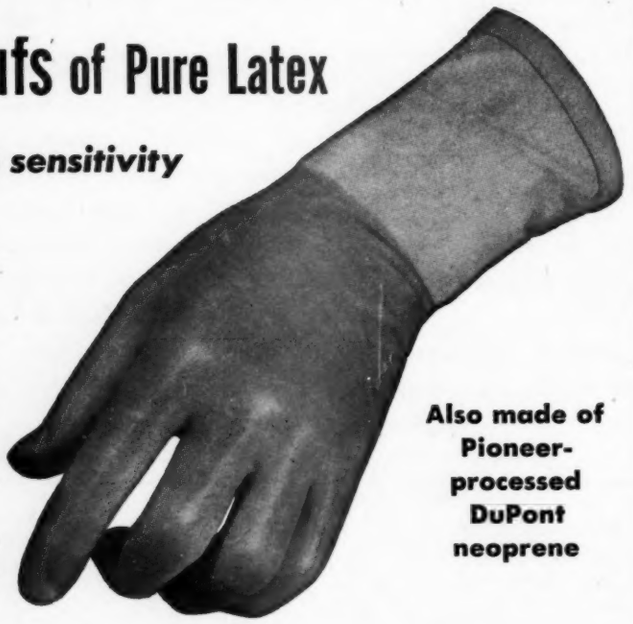

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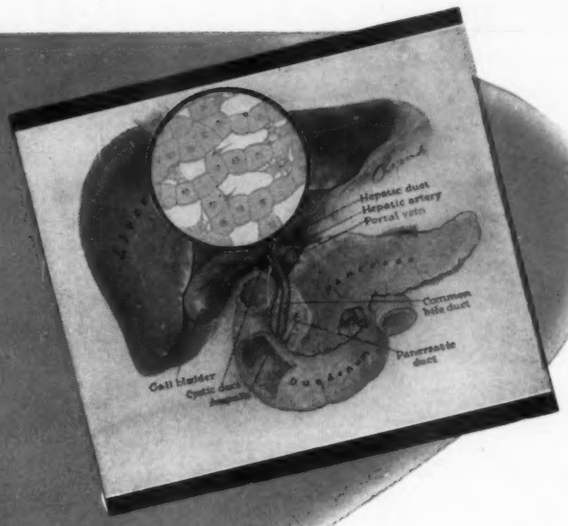

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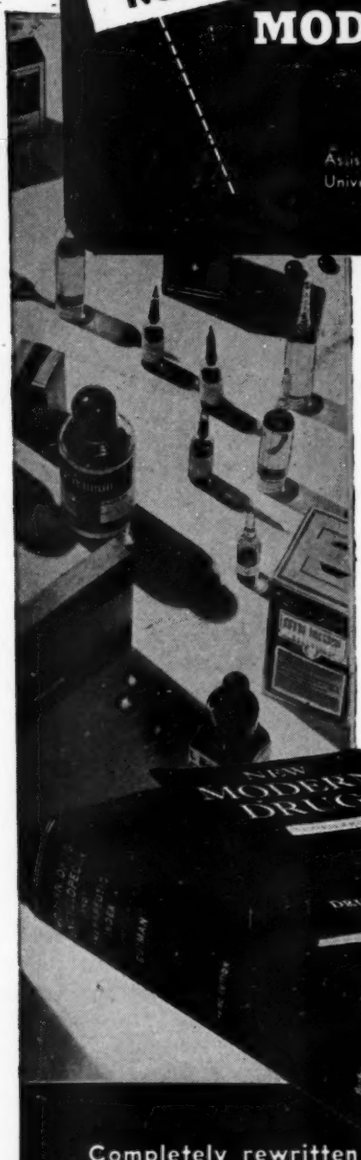

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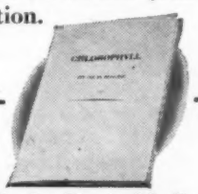

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Becton, Dickinson & Co. ..... August
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Geo. P. Pilling & Son Co. 8
Singer Sewing Machine Company ..... August
Wallace Orthopedic Supply Co. 11

Sutures

The Armour Laboratories ..... *Insert Facing p. 24*
Bauer & Black 6–7
Davis & Geck, Inc. ..... *Insert Facing 2nd Cover*
J. A. Deknatel & Sons, Inc. 40
Ethicon Suture Laboratories ..... 23, *Insert Facing p. 32*
Gudebrod Brothers Silk Co. ..... August

Pharmaceuticals

Abbott Laboratories 18
American Hospital Supply Corp. 10
The Armour Laboratories ..... *Insert Facing p. 24*
Baxter Laboratories 10
Bristol Laboratories 27
Bristol-Myers Company 47
Chatham Pharmaceutical Products, Inc. ..... August
Ciba Pharmaceutical Products, Inc. ..... 24, *Back Cover*
Cutter Laboratories 19, 33
E. Fougera & Co., Inc. ..... August
International Pharmaceutical Corp. 30
Iodine Educational Bureau, Inc. 42
Lanteen Medical Laboratories, Inc. 36
The Lavoris Company 42
Eli Lilly and Company 25
The S. E. Massengill Company 26
Merck & Company 28
McNeil Laboratories, Inc. 41
The National Drug Co. 29, 37
Parke, Davis & Co. 35
J. B. Roerig & Company ..... August
Rystan Company 45
Schering Corporation 31
Sharp & Dohme, Inc. 13
E. R. Squibb & Sons ..... August
Frederick Stearns & Company 32
Wm. R. Warner & Co., Inc. 48
White Laboratories, Inc. 16 17
Winthrop Chemical Co., Inc. 2

Hospital Supplies

A. S. Aloe Company 39
American Hospital Supply Corp. 10
Becton, Dickinson & Co. ..... August
Cutter Laboratories 19, 33
Fred Haslam & Co., Inc. 1
Johnson & Johnson 12
Macalaster Bicknell Company 22
Mallinckrodt Chemical Works ..... August
Owens-Corning Fiberglas Corp. 20
The Pioneer Rubber Co. 40

Books & Magazines

The American Journal of Medicine 21, 46
New Modern Drugs 43

Post-Graduate Instruction

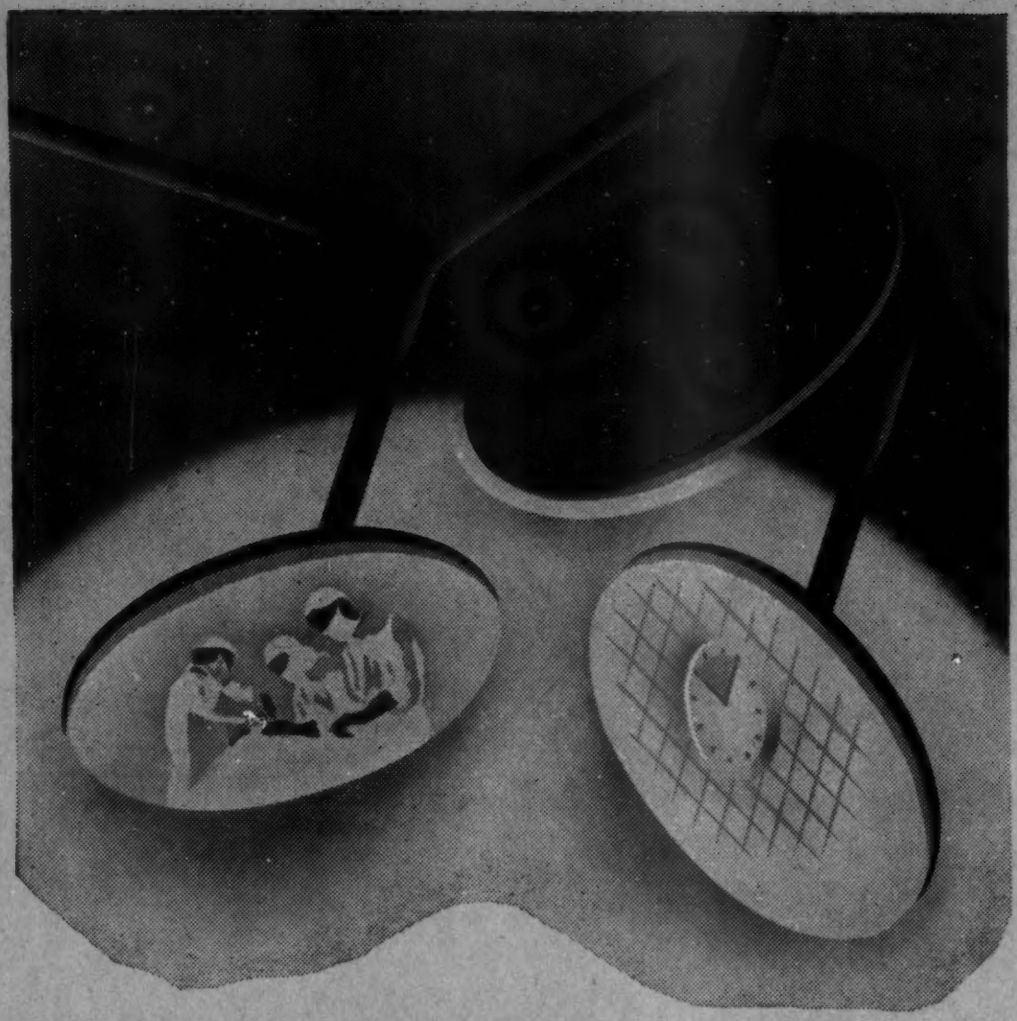
Cook County Grad. Sch. of Med. 38
N. Y. Polyclinic Med. School 38

Foods

American Meat Institute ..... August
Cereal Institute, Inc. ..... August
National Confectioners' Assn. ..... August
The Wander Company 44

Miscellaneous

U. S. Treasury 34



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